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UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND WATER RESOURCES OF OKLAHOMA

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
RECLAMATION SERVICE,
Washington, D. C., August 19, 1904.

SIR: I transmit herewith a manuscript, with illustrations, by Prof. C. N. Gould, on the "Geology and Water Resources of Oklahoma," and recommend its publication in the series of water-supply papers.

The paper was prepared under the direction of Mr. N. H. Darton, geologist in charge of the western section of the division of hydrology. It throws light upon the water resources of this section, regarding which but little has hitherto been known, and will be of considerable value in the development of this portion of the country.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

GEOLOGY AND WATER RESOURCES OF OKLAHOMA.

By Charles Newton Gould.

INTRODUCTION.

Location and general description.—Oklahoma is situated in the southern part of the Great Plains, its northern boundary being the thirty-seventh parallel of north latitude. On the west the greater part of the Territory is bounded by the one hundredth meridian, but the northwest corner, Beaver County, 35 miles in width, extends west of this meridian for a distance of 165 miles. The southern and eastern boundaries are irregular, and are sometimes rivers and sometimes parallels or meridians. In places it extends south to the thirty-fourth parallel and east to the ninety-sixth meridian.

The area of the Territory at the present time is 39,030 square miles, about that of Ohio; the population is 365,000, and the assessed value of taxable property $85,000,000. Its resources are chiefly agricultural, although minerals are known to exist in various localities. Oil and gas are present in various parts of the Territory, but Oklahoma's greatest mineral wealth consists of inexhaustible deposits of gypsum and salt, which occur chiefly in the western part of the Territory.

Sources of data.—The work which forms the basis for this report was carried on in the field and office during the years 1900–1903. In 1900 the writer was a member of a field party of the Oklahoma Geological Survey, and in 1901, in connection with Mr. Joseph A. Taff, spent a month making a map of the Wichita Mountains. In 1902 he had charge of the field parties of the Oklahoma Geological Survey, which studied the gypsum deposits in the western part of the Territory; and in 1903 made a reconnaissance in western Oklahoma, southwestern Kansas, southeastern Colorado, northern New Mexico, and the Panhandle of Texas to determine the water conditions along the upper courses of South Canadian, North Canadian, and Cimarron rivers.[a] In addition, many short trips have been made to various

[a] Gould, Chas. N., Reconnaissance in western Oklahoma and adjacent areas: Second Ann. Rept. Reclamation Service, 1904, pp. 423–432.

parts of the Territory. Since November, 1902, more tha blanks and requests for information regarding wells and spri been sent out and approximately 5,000 replies have been receiv

The writer has been very ably assisted by several advanced in the University of Oklahoma. Mr. Pierce Larkin has ha of the subject of springs, Mr. Charles A. Long of deep w Charles T. Kirk of rivers. All of these gentlemen and Mr. A. Reeds, who has also assisted in the office the past year, we bers of the field party during the season of 1903. Mr. Kirk Reeds have drawn the greater part of the maps and figures of the plates are from photographs made by Dr. A. H. Van the Oklahoma Geological Survey.

The water analysis has been made under the direction Edwin DeBarr, professor of chemistry in the University o homa, largely by his assistants, Mr. R. S. Sherwin and Mr Gridley, students in the university; and by Professors Fie Holter, of the Oklahoma Agricultural and Mechanical Colleg gypsums and clays were analyzed by Mr. Sherwin, while th analyses were compiled by Mr. Gridley.

TOPOGRAPHY.

GENERAL FEATURES.

The topographic features of Oklahoma are due to the fact is part of a region which was formerly a plain which wa down nearly to sea level, then elevated, and again eroded. T face slopes eastward at an average rate of about 8 feet to t The highest point in the Territory, approximately 4,500 fe Black Mesa, a lava-covered table-land which extends from C into the extreme northwestern corner of Beaver County. Th elevation, about 700 feet, is in the southeastern corner o Nation, where Arkansas River flows from Oklahoma into Territory. Cross sections made at various points in Oklah shown in Pl. I.

In general, the rocks of eastern Oklahoma, Kansas, and the Territory dip to the west or southwest, while the country s the east. In most localities the dip is from 10 to 20 feet to t If the surface were level, an outcropping ledge would be 1 feet below the surface 1 mile to the west of its place of outcro cause of this fact the highest rock on a north- or south-facing ment is found lower and lower in the valley to the west, until i disappears under the bed of a stream, and still farther west penetrated in a well many feet underground. In the meantin

w Plains

34°

ANDREW B GRAHAM CO LITHOGRAPHERS WASHINGTON D C

ges outcrop and in turn dip into the valley, disappear beneath the eam bed, and are succeeded by others still higher.

This peculiar combination of slope of surface and dip of rock, ether with the erosion of the exposed ledges, gives the marked air-step" structure to so much of the Great Plains. Westward hills rise constantly higher and higher. Such conspicuous forms relief as the Flint Hills, the Dakota Sandstone Hills, or the psum Hills of Kansas and Oklahoma are simply somewhat exag-rated examples of this phenomenon. These hills are more con-icuous because local conditions of sedimentation or erosion have ide them higher than the surrounding region, but there are scores less-marked escarpments.

The forms of relief of Oklahoma are the result of two factors: rst, certain broad structural zones striking in a general northeast-uthwest direction, and, second, the alternation of high divides and allow valleys resulting from stream erosion. Six streams of nsiderable size cross these structural zones, approximately at right ngles, and produce a sort of checkerboard of upland and valley, at prairie and broken country, which extends north into Kansas nd south into Texas. This arrangement, however, can be distin-uished in its broader outlines only by one who is thoroughly famil-ir with the topography of the entire region. The only exception this general topographic plan is the Wichita Mountain region, here a dome-shaped mass of igneous and lower Paleozoic rocks has een thrust up from below, afterwards surrounded by sedimentary ocks and still later extensively eroded, so that the range appears to be series of buried mountains with their tops sticking above a vast lain.

The topography of Oklahoma will be discussed with regard to the atures due to the structural zones and with reference to valley osion. On the contour map (Pl. I) the general configuration of e Territory is shown. Contour lines are lines of equal elevation ove a certain datum, and the uniform altitudinal space between djacent contour lines is called the contour interval. On this map e datum is sea level and the contour interval is 100 feet. If a per-n should follow one of these contour lines he would go neither phill nor downhill, but on a level. If an area is gently sloping, the nes are far apart; if it is a steep slope, they are crowded together; d if the slope is actually perpendicular the lines will touch. They circle the hills and recede into the reentrant angles of valleys, indi-ting both the shape and elevation of the relief forms.

UPLANDS.

With the exception of the Wichita Mountains, there are compara-vely few conspicuous relief forms in Oklahoma. In the Osage

Nation, in the northeastern part of the
bordering Arkansas River the smalle
into the hard limestone and sandstone,
and southwestern part of the Territory
that rise steeply above the level plain
In the extreme northwestern corner o
River has cut a canyon of considerable si

With the exceptions just mentioned, t
low relief. In the central and western p
areas, sometimes thousands of square m
level plain occupied by prosperous farm
cities.

Following a general classification only
line definite physiographic areas, becau

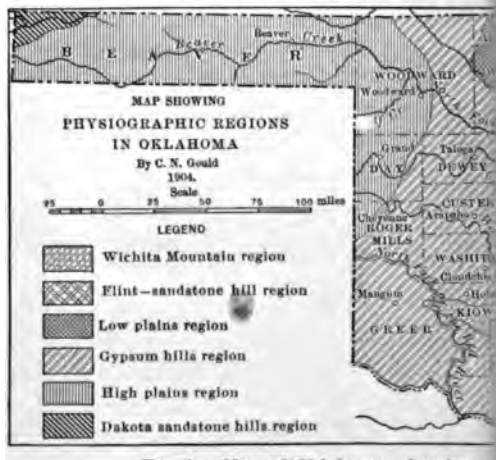


FIG. 1.—Map of Oklahoma, showing p

Oklahoma may be divided into the foll
(1) Wichita Mountain region; (2) Fl
(3) Low Plains region; (4) Gypsum Hi
region, and (6) the Dakota Sandstone
shown in fig. 1. It is possible that the th
sions correspond, at least in part, to Pr
Canadian belts.[a] Doctor Adams has p
Kansas physiographic divisions, accordi
of Oklahoma is included under Osage
Great Bend Prairie, Oklahoma Prairie,
Plains. It has not been found practica

[a] Hill, R. T., Geography and geology of the Blac
first Ann. Rept. U. S. Geol. Survey, pt. 7, 1901, p.
[b] Adams, G. I., Physiographic divisions of Kans
1903, p. 102.

A. GRANITE WEATHERING ON TOP OF QUANAH MOUNTAIN.

B. DEVILS CANYON MOUNTAIN.

of either Hill or Adams, and for this reason new terms are used. It is, however, not the intention of the writer to propose these names as any but convenient working terms for purpose of discussion.

WICHITA MOUNTAIN REGION.[a]

The Wichita Mountains constitute the westernmost of three domes or uplifts, each of which forms a separate group of mountains. Of these the easternmost, to which the term "Ouachitas" has sometimes been applied, lies in southwestern Arkansas and the southern part of the Choctaw Nation. In the Chickasaw Nation occur the Arbuckle Mountains and in southwestern Oklahoma the Wichita Mountains. Some authorities, however, notably Hill, use the term "Ouachita Mountains" to apply to the entire series of uplifts and designate the easternmost of these as the Massern ranges.[b]

The Wichita Mcuntains differ from all others in the Territory in that they are composed of igneous rocks, chiefly granite and porphyry. They have been eroded, for the most part, into peaks which vary in height from a few hundred to perhaps 1,200 feet. The main range extends west from near Fort Sill for a distance of about 30 miles, has an average width of 12 miles, and includes among others such peaks as Mount Scott, Mount Sheridan, Mount Baker, Haystack Mountain, Signal Mountain, Saddle Mountain, and Quanah Mountain (Pl. II, *A*). West of this main range to beyond the North Fork of Red River are scattered a number of smaller ranges and peaks, such as Raggedy Mountains, Mount Tepee, Devils Canyon Mountain (Pl. II, *B*), Quartz Mountain, and Headquarters Mountain. From a distance these granite peaks present the regular saw-toothed appearance noticed along the Front Range of the Rockies or in the Sierra Nevadas, with the difference that the Wichita topography is more subdued.

On the north and east for a distance of 30 miles or more is a parallel range of hills composed chiefly of hard massive limestone, and on the east and south are small rounded knobs of similar limestone. These limestone areas are remnants of a series of Paleozoic rocks which once extended as a dome over the igneous rocks, but which have been deeply eroded since the dome was uplifted.

On all sides and between these ranges of granite and limestone the rocks are composed of "red beds" shale and sandstone, with local deposits of conglomerate. In other words, at the time the red beds were being deposited the Wichitas were probably islands in the sea. The numerous creeks which head in these mountains flow either south into Red River or north into the Washita.

---

[a] For detailed discussion of the Wichitas see Taff, Joseph A., Prof. Paper U. S. Geol. Survey No. 31, 1904. The writer, as a member of Mr. Taff's party in 1901, assisted in preparing a geologic map of these mountains.

[b] Op. cit., p. 37.

FLINT-SANDSTONE HILLS REGION.

This region includes the Osage and Kaw reservations lying east c Arkansas River, Kay, Noble, Pawnee, Payne, Lincoln, and Pottawa omie counties, and the eastern part of Logan, Oklahoma, and Clev land counties. It comprises in its northern part the southern exte sion of the Flint Hills, which stretch from Nebraska across Kans into Oklahoma. Near the Kansas-Oklahoma line the Flint Hills co sist mostly of limestone ledges containing large numbers of fli concretions, interbedded with shales and sandstones, but in the Osa Nation the limestones thin out and most of the ledges disappe before Arkansas River is reached, a few only continuing as far Cimarron River. South of that stream the rocks are almost entire red shales and sandstones.

The part of Oklahoma north of the Arkansas is characterized l typical limestone topography—rounded hills and knobs, steep sha slopes with numerous rock terraces, and rather narrow valle The principal streams are Bird, Hominy, Salt, Beaver, Turkey, a Buck creeks. The rocks dip gently to the west and southwest, a the stair-step arrangement of the strata, so characteristic of certa parts of Kansas, is well exhibited. West and south of the Arkans the relief is not so pronounced, as the limestone ledges become thinn and are replaced by sandstones and shales. Streams have cut valle into the sandstone ledges, and steep but low bluffs are conspicuo In the western part of the region the topography is characteristical that of the red beds, with few forms of relief except low banks alo the streams.

LOW PLAINS REGION.

In the Low Plains region, which includes western Kay, Nob Logan, Oklahoma, and Cleveland counties, eastern Canadian, Blai and Woods counties, and the greater part of Kingfisher, Garfie and Grant counties, as well as the western part of the Chickas Nation, the topography is rolling. Steep bluffs are rare, and hi knobs are practically unknown. Rivers of considerable size—S Fork, Cimarron, North Canadian, and South Canadian—flow acr this region from northwest to southeast and have carved broad a shallow valleys. The high divides are the remnants of the old hi table, and, because their slope to the east is so gentle as to be pr tically unnoticeable, a person may travel across the country for miles along some lines without ascending or descending abrupt 20 feet from the general level. The south bluff of these rivers, f the greater part of their course, is cut up by canyons, while the slo north is generally unbroken and is covered with sand hills (p. 84).

A. UPLAND BASINS.

B. GYPSUM BLUFFS ON NORTH FORK OF RED RIVER.

GYPSUM HILLS REGION.

The Gypsum Hills region includes parts or all of Woods, Woodward, Blaine, Dewey, Day, Canadian, Caddo, Kiowa, Comanche, Greer, Washita, Custer, and Roger Mills counties, in each of which there are exposures of gypsum. In this section the relief is more marked than in the Low Plains region, owing chiefly to the unequal erosion consequent upon the relatively hard ledges of gypsum which outcrop in this part of the territory and to the hard sandstone and dolomite which lie above the gypsum. The relation between these rocks will be explained under the heading "Geology" (pp. 44, 71). The general strike of all the gypsum beds is north and south, the most eastern exposure being just north of El Reno, the county seat of Canadian County, while to the southwest the gypsum ledges extend, through Greer County, into the Panhandle of Texas.

There are two prominent types of gypsum topography in Oklahoma—the wall-canyon type and the round-mound type. The wall-canyon type occurs chiefly in Blaine, Woods, and Woodward counties along the range of gypsum hills designated in this report the Blaine Gypsum Hills, and again in southern Roger Mills and northern Greer counties (Pl. III, *B*). This type of topography is characterized by steep bluffs of red clay capped by massive ledges of gypsum. These bluffs rise steeply above the plain, and numerous streams have cut deep and narrow canyons into them. The second type of gypsum topography is marked by low, white, rounded, gypsum knolls standing out on the plain, or by gentle slopes of gypsum along shallow streams. Such exposures are characteristic of parts of Dewey, Custer, Washita, Caddo, and southern Greer counties.

HIGH PLAINS REGION.

This region includes the most elevated portions of the Territory, and is typically developed in Beaver, Woodward, and northern Day counties, lying west of and at a higher level than the line of gypsum hills. Beaver County, an area 165 miles long and 35 miles wide, lies entirely on the high, level plateau, sloping gradually from a height of about 4,000 feet on the west to a little more than 2,000 on the east. Into this plateau Cimarron and Beaver rivers have cut their channels, usually shallow and broad, while numerous small tributary creeks are now at work dissecting the level upland. Large areas remain, however, which appear to be as level as a floor and on which the only drainage is into playa lakes, or, as they are sometimes called in the West, "buffalo wallows" (Pl. III, *A*).

DAKOTA SANDSTONE REGION.

In the extreme western end of Beaver County, along the Cimarron and the Currumpaw (a head tributary of the Beaver), is a small area which contains topographic features unlike those found elsewhere in Oklahoma, for in this locality the streams have cut canyons into the Dakota sandstone. The Cimarron Canyon has a length of 30 miles or more in Oklahoma and of 60 miles in New Mexico. The hills, as shown on Pls. IV, *B*, and X, *B* are 200 to 500 feet high, and are usually capped by heavy ledges of gray or brown sandstone, which have been carved into fantastic shapes by numerous small creeks.

In the extreme northwestern part of Beaver County these sandstone rocks are covered with 100 feet or more of basaltic lava, forming the eastern end of Black Mesa, a level table-land which extends into Oklahoma from Colorado and New Mexico (fig. 28).

VALLEYS.

All the drainage of Oklahoma flows into Mississippi River, reaching that stream by Arkansas and Red rivers. The Arkansas crosses the northeast portion of Oklahoma, separating the Osage and Kaw reservations from the remainder of the Territory. Red River forms the extreme southwestern boundary of Oklahoma. The chief tributaries of the Arkansas in Oklahoma and the Indian Territory are Salt Fork, Cimarron, North Canadian, and South Canadian rivers, the two latter streams joining before finally reaching the Arkansas in the eastern part of the Territory. The Washita and North Fork of Red River flow into Red River.

The general direction of all these streams is southeasterly—that is, practically at right angles to the strike of the rocks. With the exception of the Washita, they are all typical streams of the plains, each with a relatively broad and shallow valley, containing a broad, sand-choked channel and, except in times of flood, carrying a relatively small amount of water. The character of these valleys is determined largely by the rocks across which they have been cut, being comparatively narrow and deep in the Gypsum Hills or Flint Hills regions and broad and shallow in the more level country in central and western Oklahoma. These valleys will be discussed in regular order beginning on the north. Pl. XVI shows the drainage areas of the various streams.

ARKANSAS VALLEY.

Arkansas River flows in a broad, shallow channel from the point where it debouches from the mountains, in Colorado, to the Flint

A. DAKOTA EROSION NEAR KENTON, OKLA., SHOWING CROSS-BEDDING.

B. EROSION FORMS IN DAKOTA CRETACEOUS.

DAKOTA SANDSTONE REGION.

In the extreme western end of Beaver County, along the Cimarron and the Currumpaw (a head tributary of the Beaver), is a small area which contains topographic features unlike those found elsewhere in Oklahoma, for in this locality the streams have cut canyons into the Dakota sandstone. The Cimarron Canyon has a length of 30 miles or more in Oklahoma and of 60 miles in New Mexico. The hills, as shown on Pls. IV, *B*, and X, *B* are 200 to 500 feet high, and are usually capped by heavy ledges of gray or brown sandstone, which have been carved into fantastic shapes by numerous small creeks.

In the extreme northwestern part of Beaver County these sandstone rocks are covered with 100 feet or more of basaltic lava, forming the eastern end of Black Mesa, a level table-land which extends into Oklahoma from Colorado and New Mexico (fig. 28).

VALLEYS.

All the drainage of Oklahoma flows into Mississippi River, reaching that stream by Arkansas and Red rivers. The Arkansas crosses the northeast portion of Oklahoma, separating the Osage and Kaw reservations from the remainder of the Territory. Red River forms the extreme southwestern boundary of Oklahoma. The chief tributaries of the Arkansas in Oklahoma and the Indian Territory are Salt Fork, Cimarron, North Canadian, and South Canadian rivers, the two latter streams joining before finally reaching the Arkansas in the eastern part of the Territory. The Washita and North Fork of Red River flow into Red River.

The general direction of all these streams is southeasterly—that is, practically at right angles to the strike of the rocks. With the exception of the Washita, they are all typical streams of the plains, each with a relatively broad and shallow valley, containing a broad, sand-choked channel and, except in times of flood, carrying a relatively small amount of water. The character of these valleys is determined largely by the rocks across which they have been cut, being comparatively narrow and deep in the Gypsum Hills or Flint Hills regions and broad and shallow in the more level country in central and western Oklahoma. These valleys will be discussed in regular order beginning on the north. Pl. XVI shows the drainage areas of the various streams.

ARKANSAS VALLEY.

Arkansas River flows in a broad, shallow channel from the point where it debouches from the mountains, in Colorado, to the Flint

A. DAKOTA EROSION NEAR KENTON, OKLA., SHOWING CROSS-BEDDING.

B. EROSION FORMS IN DAKOTA CRETACEOUS.

Hills, at Arkansas City, Kans., a few miles north of the Oklahoma line. From this point to the southeast corner of the Osage Nation it flows in a tortuous channel among limestone hills. The distance is about 83 miles direct, but as traversed by the river it is nearly twice as great. This part of its course is characterized by broad and sweeping oxbow bends, one, for instance, being 9 miles around, while at the nearest point it is not more than 1½ miles across. The valley between the bluffs, which are 150 to 300 feet high, is 1 to 5 miles wide, being narrowest between the Osage country and Kay County.

SALT FORK VALLEY.

The valley of the Salt Fork of the Arkansas, which extends through northern Woods, central Grant, and southern Kay counties, is broad and shallow and is for the most part bordered on the north slope by sand hills and on the south side by canyons cut into steep and uneven slopes. Near the point where this river enters Woods County from Kansas the valley is bordered by the Gypsum Hills, particularly on the south side, while farther downstream it is 2 to 5 miles wide and the hills on either side reach an altitude of 50 to 100 feet above the level of the stream. The tributaries are Medicine Lodge, Mule, Sand, Crooked, Deer, Osage, Buck, Chikaskia, and Bois d'Arc creeks. In eastern Woods County the Salt Fork flows across the northern edge of the Great Salt Plains, where the water acquires saline character, whence the name Salt Fork.

CIMARRON VALLEY.

Cimarron River rises among volcanic peaks in northern New Mexico, flows east through a narrow canyon cut into Dakota sandstone, and enters Oklahoma 4 miles south of the Colorado line, near the town of Kenton. From this point it flows nearly straight east for more than 30 miles in a canyon cut in the sandstone plateau. In this part of its course the valley averages 3 miles in width and the rugged hills, which disappear near the point where the Cimarron flows from Oklahoma into Colorado, are 300 to 400 feet high. From this point to the place where the river cuts through the Gypsum Hills it flows in a broad and shallow valley carved into the level upland. After leaving Oklahoma the Cimarron flows through southeastern Colorado and southwestern Kansas for nearly 100 miles. It enters the Territory again about 15 miles west of the northeast corner of Beaver County, but soon turns northward to pass into Kansas. For the third time it enters Oklahoma, in the north-central part of Woodward County, where it breaks through the Blaine Gypsum Hills. Throughout its entire course in Woodward County,

a distance of more than 40 miles, it flows in a canyon cut ir Gypsum Hills. This canyon gradually widens to the east, and the western line of Woods County these hills recede from the and swing to the north. On the south side, however, they paralle river as far as the Glass Mountains in south-central Woods Co forming conspicuous gypsum-capped bluffs, then gradually r from the Cimarron and approach the South Canadian. East o Glass Mountains the Cimarron flows across a level country, an valley is broad and shallow, being only occasionally lined with b as in the vicinity of Guthrie.

The drainage area of the Cimarron is broader than that of other Oklahoma stream, and it includes a considerable numb tributary creeks, the chief of which are Buffalo, Eagle Chief, Turkey, Kingfisher, Cottonwood, Skeleton, and Stillwater. A its eastern course the river flows into the southern extension o limestone hills, where the topography consequently is more un and bluffs 100 or more feet high are not uncommon.

NORTH CANADIAN VALLEY.

North Canadian River is formed by the junction of Beaver Wolf creeks at Old Fort Supply, near the center of Woodward Co Wolf Creek rises in the high table-lands of the Panhandle of T and flows northeast, in a rather narrow valley bordered by rou bluffs which rarely exceed 100 feet in height. Beaver Creek, w has cut a valley averaging 3 miles in width and 200 feet in d throughout its course, rises among volcanic peaks in northea New Mexico and flows the entire length of Beaver County. principal tributaries, all on the south side, are Coldwater, Palo I Clear, and Kiowa creeks. These and other creeks are now disse the high plateau, but on account of the arid climate and the sod covering have, at the present time, scarcely more than comm their task (Pl. V, A). North Canadian River formed by the of Wolf and Beaver creeks, flows in a general southeasterly c entirely across the Territory, and its valley is, on the average feet higher than the Cimarron. The hills on either side are us low, often not over 100 feet in height, and in many instance headwaters of streams flowing into the Cimarron approach w less than 2 miles of the North Canadian. Sand hills occur tically all along the north slope, and the south bluff is often cut red-beds canyons.

SOUTH CANADIAN VALLEY.

With the exception of Arkansas River the South Canadian i only stream in Oklahoma which takes its rise in the Rocky M

A. PRAIRIE STREAM JUST BEGINNING TO CUT.

B. PIT HOLES ALONG PRAIRIE ARROYO.

tains. In New Mexico and the Panhandle of Texas the drainage area is large, but from the western boundary of Oklahoma to its mouth in the eastern part of the Indian Territory it will not average more than 20 miles in width. In Day and Dewey counties the river swings in a series of broad oxbow bends, and flows in a canyon-like valley about 200 feet deep and 1 to 5 miles wide. In eastern Dewey and Custer counties it flows across the Gypsum Hills region. Below the line of Gypsum Hills it flows in a general southeasterly direction in a valley which averages 4 miles in width and which is bordered by bluffs on either side not exceeding 150 feet in height. In many places, however, the slopes north of the river are covered with sand hills, but on the south side of the stream steep bluffs are common. A few small tributaries, the chief of which are Deer, Commission, and Boggy creeks, flow into the South Canadian in Oklahoma.

WASHITA VALLEY.

As has been stated by Mr. Willis,[a] the Washita resembles an eastern more than a western river, having steep mud banks and heavy timber along most of its course. In its upper part the narrow valley is continued between bluffs of red sandstone 100 to 300 feet high. Where the valley cuts across the Gypsum Hills, in Custer and Washita counties, low, white gypsum bluffs are common. Eastward from the southeastern corner of Washita County the river flows through wide bottom lands in a valley 2 to 5 miles wide, inclosed by hills 100 to 300 feet high. Taken throughout, the Washita has more precipitous bluffs and a greater diversity of topography than any other river in Oklahoma, and at the same time sand hills are practically wanting. Quartermaster, Cavalry, Rainy Mountain, Cobb, and Sugar creeks are the chief tributaries.

RED RIVER VALLEY.

The main branch of Red River forms the southern boundary of Greer and Comanche counties. A number of streams tributary to Red River rise either in Oklahoma or the Panhandle of Texas, the most important of which are the Salt Fork, Elm Fork, North Fork, Cache, and Beaver creeks. North Fork, Salt Fork, and Elm Fork rise in the eastern part of the Panhandle of Texas, flow across the region of Greer Gypsum Hills through canyons in the gypsum-capped red shale bluffs and then out upon the lower plains, where they enter shallow valleys before finally reaching Red River. Cache Creek, which rises in the Wichita Mountains, and Beaver Creek, east

[a] Willis, Bailey, First Ann. Rept. Reclamation Service, U. S. Geol. Survey, 1903, p. 269.

of these mountains, flow south across the red beds plain in broad and shallow valleys.

CONCLUSION.

All of the larger rivers of Oklahoma rise west of the Gypsum Hills region and flow first in broad valleys. In the Gypsum Hills they have cut comparatively deep and narrow canyons, and east of this range of hills the valleys begin to widen again. These streams, with the exception of the Washita, are flanked along the north slope with rows of sand hills, usually 2 to 10 miles in width, while the south bank is almost invariably cut with canyons carved in the red sandstones and shales which make up the greater part of the country rock. In other words, the south bank is a red-shale canyon slope, and the north bank a sand-hill slope.

GEOLOGY.

GENERAL STATEMENT.

The geology of Oklahoma presents certain phases of more than usual interest to the student of stratigraphy. As the conditions of the water supply depend almost wholly upon the character and position of the rocks, it is necessary to outline the geology of the Territory before giving a detailed description of the water supply.

Numerous features of the geology of various parts of Oklahoma are as yet but imperfectly understood, and many of the statements made in this article therefore are offered only tentatively. It is probable that further investigation may cause decided changes in present views of the geology of certain parts of the Territory, especially as to the line of separation between the Pennsylvanian and Permian series of the Carboniferous rocks in the northeastern part of the Territory, the location of certain sand-hill areas, and the lines of outcrops of gypsum deposits in some of the western counties. Certain facts, however, are fairly well established, and it is these, rather than the ones not yet understood, that will be given prominence in the following pages.

The principal formation in the Territory is a widespread deposit of red clay, shale, and sandstone, a large part of which has been classed as Permian in age, and is known as the "red beds." To the east it is underlain by Pennsylvanian rocks and to the west covered by sands and clays of Tertiary and Quaternary ages. In the northeastern part of the Territory are extensive areas of Pennsylvanian rocks, and in the Wichita Mountains rocks of lower Paleozoic age appear. The known outcrops of geologic formations in Oklahoma are indicated on the map (Pl. I), and the following table sets forth their order and age:

Quaternary	Alluvium.	
	Sand hills.	
Tertiary	Lava of Black Mesa.	
Cretaceous	Dakota.	
	Comanche.	
Carboniferous	Permian	Quartermaster.
		Greer.
		Woodward.
		Blaine.
		Enid.
	Pennsylvanian.	
Ordovician	Viola limestone.	
Cambro-Ordovician	Arbuckle limestone.	
Cambrian	Reagan sandstone.	
Early Cambrian or older	Granite.	
	Granite-porphry.	
	Gabbro.	

RELATIONS OF THE PRE-CARBONIFEROUS ROCKS.

The oldest rocks in Oklahoma are in the Wichita Mountains, in the southwestern part of the Territory. These mountains are composed chiefly of three classes of igneous rocks, gabbro, granite, and granite-porphyry; and three sedimentary formations of lower Paleozoic age, the Reagan sandstone, Arbuckle limestone, and Viola limestone. Granite greatly predominates, composing probably nine-tenths of all the rocks of the range. In order that the reader may understand the relations of these various rocks to each other and the surrounding "red beds," a short description of the Wichita Mountains is given. The map (Pl. VI) further illustrates the structure of the mountains.

In the Wichita Mountains the rocks do not differ materially from similar formations in the Arbuckle Mountains farther east, and for that reason it appears to be desirable to give the formations the names already used for similar rocks in the Arbuckle region. As these rocks have been named and described by Mr. Joseph A. Taff,[a] to whose publication the reader is referred, only a brief mention will be made of them in this conection.

The extreme length of the Wichita Mountains, from the Carlton mounds on Medicine Bluff Creek near Fort Sill to the last granite hill that disappears under the high prairie 5 miles west of Headquarters Mountain, at Granite, is 65 miles, while the extreme width from Rainy Mountain to the southwestern granite butte on North Fork of Red River, 6 miles southeast of Navajoe, is 30 miles. The Wichita Mountains are not a continuous range throughout this area,

[a] Taff, Joseph A., Preliminary report on the geology of the Arbuckle and Wichita mountains in Indian Territory and Oklahoma: Prof. Paper No. 31, U. S. Geeol. Survey, 1904, pp. 50–81.

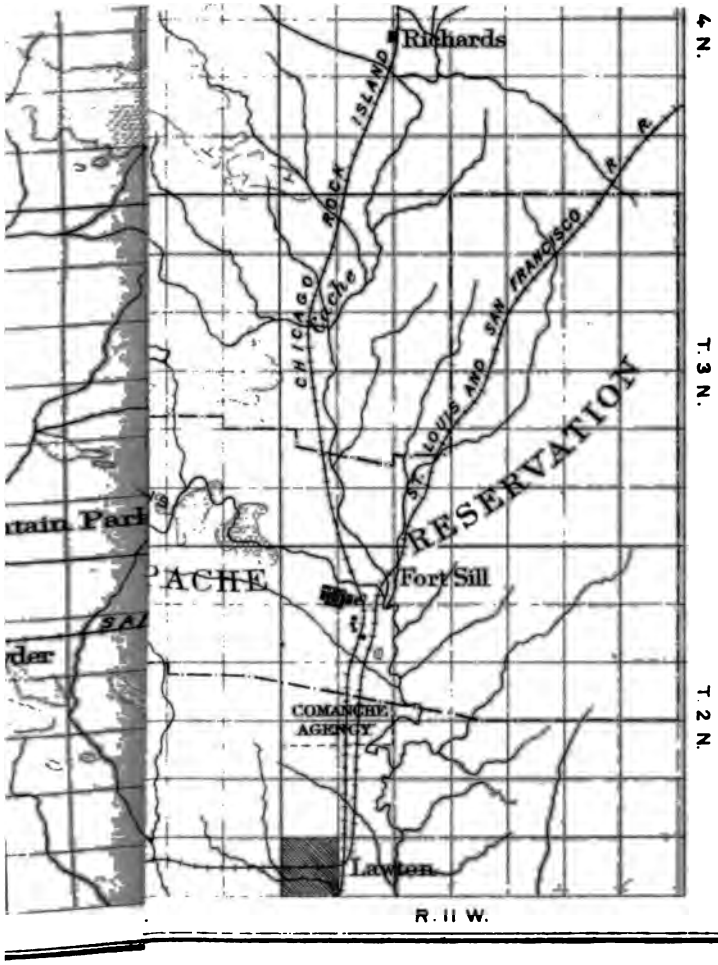
as they consist chiefly of scattered ranges, peaks, and short chain the bases of which are buried beneath the surrounding and interven ing plains.

The Wichita Mountains may be divided into the following thre general groups: (1) The main range; (2) scattered groups and peak in the western part of the area, and (3) a row of hills which ar composed chiefly of limestone and which parallel the main range o the north and east.

The main range of the Wichita Mountains, the width of whic averages 10 miles, extends northwest from the vicinity of Fort Sil for about 30 miles to the vicinity of Saddle Mountain and Moun Baker, just east of the headwaters of East Otter Creek. This par of the range is practically continuous throughout and is compose chiefly of rugged peaks of granite, the highest of which, Mount Scott and Sheridan, each rise about 1,200 feet above the plain. Ther are two main northwest-southeast ranges, separated by a distinc intermontane valley, 1 to 4 miles wide, extending nearly the entir length of the ranges. The streams draining this valley flow eas and south and escape to the plain through gaps in the mountains East of this main range are a number of outlying peaks and shor ranges, some of which attain an altitude of 800 feet or more abov the surrounding plain.

West of the main range of the Wichitas, which is divided int two general ridges, are scattered groups, peaks, and low ridge extending a few miles beyond Granite, Greer County, a distance o 40 miles from Mount Baker. The term "Raggedy Mountains" i applied to a group of scattered, roughly outlined ridges and peak lying along the heads of various branches of Otter Creek. Lon Horn Mountain is near the head of Middle Otter Creek; Dom Mountain, Tepee Mountain, Elk Mountain, and others lie near El Creek; Devils Canyon Mountain, shown in Pl. II, *B*, is 6 miles lon and lies in a bend of the North Fork of Red River; Navajoe, Quart and Headquarters mountains are in Greer County west of the Nort Fork of Red River, which winds in and out among the granite peak

Parallel to the Wichitas on the northeast from a point 7 mil north of Fort Sill to Rainy Mountain, a distance of 30 miles to th northwest, is a group of limestone hills, which, like the main rang of the Wichitas, consist of irregular low mountains and scattere knobs. The longest range, 16 miles in length, will average 2 mil in width. Near the head of Blue Creek Canyon the range of lime stone hills divides into two parts—one part running approximatel N. 70° W. and the other N. 40° W. Both ranges finally end toward the northwest in a series of scattered peaks and knobs. These lime stone hills, like the granite mountains, are but the tops of buried


Richards
ISLAND
ROCK
CHICAGO
Cache
ST. LOUIS AND SAN FRANCISCO
R.
R.
RESERVATION
Fort Sill
PACHE
COMANCHE
AGENCY
Lawton
4 N.
T. 3 N.
T. 2 N.
R. 11 W.

ranges. The rock comprising the plain around and between the mountains is much younger than the rocks of the mountains—that is, it was deposited at a much later period in the earth's history.

IGNEOUS ROCKS.[a]

GABBRO.

Of the three chief varieties of igneous rocks in the Wichitas the gabbro is probably the oldest. This rock is hard, black, and crystalline, and sometimes is known to the miners as black granite. It frequently has a greenish tint, or again it may be grayish in color, and often weathers into rough, lumpy surfaces. It is in places cut by dikes, composed of diabase, granite, aplite, etc.

As shown on the map (Pl. VI) gabbro outcrops in three separate localities in the Wichita Mountains, two of which are in the main range and the other one west of it. In the main range the most extensive exposure, which covers an area about 2 miles wide and 12 miles long, lies along the north slope of the mountains on both sides of Medicine Bluff Creek, and extends northwest and southeast, paralleling the range from the east end of Mount Scott to the east slope of Saddle Mountain. The second gabbro exposure, about 6 miles long and 1 mile wide, is in the central part of the intermontane valley along the heads of West Cache and Quanah creeks. The gabbro in both these localities does not, as a rule, present conspicuous relief, but weathers into gentle slopes with occasional low ridges and buttes. The third locality in which gabbro is found is in the central part of the Raggedy Mountains, west of the main range. This range is 15 miles long and extends westward from near Mount Baker to a point within 3 miles of North Fork of Red River. Some of the peaks rise to the height of 400 feet above the plain. The average width of the range is something like 3 miles, and across it flow the various branches of Otter Creek. In the western part of the range are numerous dikes and intrusions of other igneous rocks, chiefly granite and quartz.

GRANITE-PORPHYRY.

Granite-porphyry occurs in the eastern part of the main range and in several localities among the limestone hills. This is a hard, massive rock usually with a grayish groundmass in which are embedded numerous large crystals, usually reddish or pinkish, giving a characteristic reddish-gray tint to the rock. The localities in which porphyry occurs are as follows:

In the Fort Sill Military Reservation and between the fort and

[a] For classification of the igneous rocks of the Wichita Mountains see Taff, Joseph A., op. cit., pp. 59–67.

Mount Scott the greater part of the rock is granite-porphyry. Signal Mountain, the Carlton mounds, Medicine Bluff, and a number of unnamed peaks are composed of this rock. This porphyry weathers in small blocks and angular fragments, and the surface of the hills composed of this rock are usually grass covered and easily distinguished from granite hills in which the rock weathers out in large bowlders and which are covered with trees. In the western part of this exposure the porphyry passes gradually into red granite, so that in many places it is virtually impossible to tell where one rock stops and the other begins.

Near the central part of the main ridge of limestone hills, 6 to 8 miles north of Mount Scott, along Blue Creek Canyon, is a second exposure of porphyry covering an area of about 8 square miles The rock in this region does not differ materially in character from that on the Fort Sill Reservation. On the west the porphyry is cut off from the limestone by a fault and on the east, where it is exposed along the flanks of a limestone ridge, it lies unconformably below the sedimentary rocks.

The third area of porphyritic rocks is in the extreme northern part of the Wichita Mountain region, at the northern extension of the limestone hills. In this vicinity are twelve or more scattered peaks of porphyry. In two instances this porphyry lies unconformably below the Reagan sandstone, a formation of Cambrian age.

GRANITE.

With the exception of the gabbro and granite porphyry just discussed and a relatively few dikes, the igneous rocks of the Wichitas consist of granite, which varies in color from red to gray with light red greatly predominating. It is cut by several series of joint planes and weathers into massive bowlders (Pl. II, *A*, *B*).

The high peaks of the main range, such as Mounts Scott, Sheridan and Baker, and Saddle Mountain, and others, as well as all the scattered peaks and ranges west of the main range, except the gabbro range previously discussed, are composed of granite. Navajoe Tepee, Devils Canyon, Little Bow, Quartz, Headquarters, and other peaks and chains in this western group are all granite mountains.

SEDIMENTARY ROCKS.[a]

CAMBRIAN ROCKS.

REAGAN SANDSTONE.

The Reagan sandstone, the oldest sedimentary rock in Oklahoma in its typical development is composed of coarse-grained, angula

[a] For a more complete description see Taff, Joseph A., op. cit., pp. 67–77.

particles derived from the disintegration of porphyry rocks. There are local ledges of conglomerate interstratified with shaly members, but coarse sandstone makes up the greater part of these rocks. The age of this formation, as indicated by trilobites and other fossils, is Middle Cambrian.

The Reagan formation is exposed on the granite-porphyry, and it is conformably overlain by the Arbuckle limestone at two localities; first, in the limestone hills east of Blue Creek Canyon, and second, along the side of some limestone peaks in the extreme northern part of the mountains. At Blue Creek Canyon the Reagan is exposed for a distance of nearly 4 miles, while farther north the line of outcrop is not more than 2 miles long. In both localities the exposure is but a few hundred feet wide.

CAMBRO-ORDOVICIAN ROCKS.

ARBUCKLE LIMESTONE.

Conformably above the Reagan sandstone is a limestone formation which makes up the greater part of the northern division of the Wichita Mountains. This limestone is hard, compact, and massive, and is at nearly all places much folded and faulted, so that its beds rarely lie level, but have been broken and tilted to various angles, usually steep. The thickness of this formation in the Wichita Mountains is unknown, but in the Arbuckle Mountains it was estimated by Mr. Taff to be 4,000 to 6,000 feet, and there is no reason for supposing that it is less in the Wichitas. In the Arbuckle Mountains the lower 700 feet of this limestone contains fossils of Upper Cambrian age, while from the upper beds Ordovician forms were obtained.

The hills composed chiefly of this limestone extend practically uninterrupted northeast from near Fort Sill for 30 miles or more. From the region of Blue Creek Canyon there are two ranges, both of which finally die out and disappear beneath the plains.

ORDOVICIAN ROCKS.

VIOLA LIMESTONE.

Three small outlying limestone knobs in the vicinity of Rainy Mountain Mission consist of Viola limestone, an Ordovician formation, which in the Arbuckle Mountains occurs approximately 2,000 feet higher in the section than the Arbuckle limestone. In the Wichita Mountain region little lithologic distinction can be made between the limestone comprising these knobs and the limestone which makes up the main range of hills just described. Mr. E. O.

Ulrich, however, who studied the fossils from the entire region, finds that the paleontologic evidence justifies such distinction, and for that reason the rocks composing the three hills near Rainy Mountain are classed as Viola.

CARBONIFEROUS ROCKS.

PENNSYLVANIAN SERIES.

GENERAL RELATIONS.

The oldest rocks on the plains consist of scattered groups of igneous rocks, chiefly granite, forming the hearts of the Ozark, Arbuckle and Wichita mountains. The greater part of the Ozark and Boston mountains in Missouri and Arkansas consist of sedimentary rocks older than the Coal Measures, chiefly limestones and cherts of the Mississippian ("Lower Carboniferous"). Rocks of the same age are also found in southeastern Kansas and the eastern part of the Cherokee Nation. Westward the rocks belong to successively younger formations.

Resting upon the Mississippian in Indian Territory is a great thickness of rocks of Pennsylvanian age.[a] These rocks occupy the greater part of southern Iowa, western Missouri, eastern Nebraska, and the eastern third of Kansas. Large outcrops are also found in Arkansas and Texas.

Pennsylvanian rocks are exposed over a considerable area in eastern Oklahoma. The line of separation between the Pennsylvanian and the Permian, which make up the greater part of the Territory, has never been sharply drawn. For reasons to be discussed later this line can not be drawn with any degree of accuracy until considerable work has been done in the way of tracing formations in northeastern Oklahoma and until fossils have been collected and identified.[b]

RELATION OF THE PENNSYLVANIAN TO THE PERMIAN.

The problem of the relation of the Pennsylvanian to the Permian on the Great Plains is at best a perplexing one. Perhaps more time has been spent in attempting to solve it than has been devoted to almost any other phase of western geology, and the results have been less satisfactory. In Kansas the rocks of these two epochs have been studied for nearly fifty years, and during the past ten years Willis

[a] Taff, Joseph A., The southwestern coal fields: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 367–413; Geology of the McAlester-Lehigh coal fields, Indian Territory: Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 423–593, 1899; Eastern Choctaw coal fields, Indian Territory, Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 255–311, 1900; Coalgate Folio, No. 74, 1901, and Atoka Folio, No. 79, 1902. Drake, N. F., A geological reconnaissance of the coal fields of the Indian Territory: Proc. Am. Philos. Soc., vol. 36, 1898, pp. 326–429.

[b] See footnote, p. 32.

ton,[a] Cragin,[b] Prosser,[c] Hay,[d] Beede,[e] and others have contributed articles which have assisted in the elucidation of this very perplexing question. In Kansas, however, the difficulties are not so great as in Oklahoma, as in Kansas the Pennsylvanian rocks which occur in the eastern third of the State are in a regular, conformable succession, and finally pass conformably into the Permian above. Many of the beds have lithologic characteristics, and fossils are abundant. It is true that the line of separation between the Pennsylvanian and Permian has not been sharply drawn, for such a line depends upon paleontologic rather than upon lithologic data, and in certain strata there is a commingling of Pennsylvanian and Permian forms, but most geologists who have studied the problem have agreed that certain rocks are Pennsylvanian in age and that certain other rocks, several hundred feet higher geologically, belong to the Permian.

In parts of Texas where these rocks are well exposed the line of division between the two series has been fairly well worked out. Certain beds are known to be Pennsylvanian, while certain other higher beds are undoubtedly of Permian age.

In Oklahoma, on the other hand, such conditions do not exist. In the northeastern part of the Territory particularly the stratigraphy is exceedingly perplexing and at the same time fossils are rare. On the geological map (Pl. I) the author has attempted to outline the conditions as they are believed to exist. From this map it will be seen that the greater part of the Osage Nation, which is in the northeast corner of Oklahoma, is underlain by rocks of Pennsylvanian age. In this part of the Territory, as in Kansas to the north, the strike is to the northeast and southwest, and many of the ledges, notably certain limestones, have been traced by Adams[f] and others from Kansas into Oklahoma, some to beyond Arkansas River. The lowest limestone ledge that is known in the Osage Nation (although more detailed study will probably reveal others still lower) is the Drum limestone which has been traced as far south as the vicinity of Bartlesville, in

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[a] Williston, S. W., Science, new series, vol. 5, p. 395; Kansas Univ. Quar., vol. 6, p. 57; Jour. Geol., vol. 6, 1898, p. 342.

[b] Cragin, F. W., Bull. Washburn Col. Nat. Hist., vol. 1, 1885, p. 86; id., vol. 2, 1889, pp. 33, 34; The Permian system of Kansas: Colorado Col. Studies, vol. 6, 1896, pp. 1–48; Observations on the Cimarron series: Am. Geologist, vol. 19, pp. 351–363.

[c] Prosser, Chas. S., The Cimarron series or the Red Beds: Second Ann. Rept. Univ. Geol. Survey Kansas, 1897, pp. 75–95; The Permian and Upper Carboniferous of southern Kansas: Kansas Univ. Quar., vol. 6, 1897, pp. 149–176; Revised classification of the upper Paleozoic formations of Kansas: Jour. Geol., vol. 10, 1902, pp. 703–737.

[d] Hay, Robt., A geological reconnaissance in southwestern Kansas: Bull. U. S. Geol. Survey No. 57, 1890, pp. 20, 27; Eighth Bien. Rept. Kansas State Bd. Agric., pt. 2, 1893, p. 101.

[e] Beede, J. W., Jour. Geol., vol. 9, 1901, p. 339; Am. Geologist, vol. 28, 1901, pp. 46, 47; Advance Bull. First Bien. Rept. Oklahoma Geol. Survey, April, 1902.

[f] Adams, Geo. I., Stratigraphy and paleontology of the Upper Carboniferous rocks of the Kansas section: Bull. U. S. Geol. Survey No. 211, 1903.

the Cherokee Nation, just east of the Oklahoma line. If the direction of the strike of this rock remains constant, however, this ledge should touch the Arkansas not far from the mouth of the Cimarron, and if so, there are probably several hundred feet of Pennsylvanian rocks in Oklahoma below the level of the Drum limestone.

Another ledge of limestone, the Pawhuska, has been traced by Adams from Kansas south through the Osage Nation and across Arkansas River to the vicinity of the Cimarron, near Ingalls, Payne County, Okla.[a] The Pawhuska, however, is stratigraphically 600 feet below the base of the Wreford limestone, which is now considered by Prosser to be the base of the Permian.[b] The Drum limestone is approximately 950 feet below the Pawhuska, so that in the Osage Nation there are at least 1,550 feet of the Pennsylvanian rocks below the base of the Permian.

This part of the problem presents no great difficulty. The point which leads to confusion is the failure to identify many of these prominent ledges in the region south of Arkansas River. Within a belt 50 miles wide on either side of the river the lithologic conditions change rapidly. At the Kansas-Oklahoma-Indian Territory line there are, between the Drum limestone and the Winfield formation, which is the highest prominent limestone ledge in the Permian, no fewer than 16 heavy beds of limestone, varying in thickness from 5 to 40 feet. On passing southward through the western part of the Cherokee Nation and the Osage Nation these limestones become thinner and less conspicuous, while at the same time the intervening shales become thicker and more prominent, often becoming arenaceous, or, indeed, replaced entirely by sandstone, until by the time the Arkansas River is reached the greater part of these limestone formations have totally disappeared, while those that remain have become much thinner, and the rocks consist entirely of alternating layers of sandstone and shale. In the light of our present knowledge it is believed that the Pawhuska limestone extends farther south than any of the others. This limestone was traced by Mr. Pierce Larkin as far south as a point 9 miles south of Chandler, where it seems to disappear and its place is taken by shales and sandstones. At the same time the shales, which have been of a prevailing drab, bluish, or yellowish color, become more and more reddish, until they gradually merge into the typical brick-red shales and clays that make up the greater part of the Oklahoma red beds.

This condition was first pointed out by Dr. George I. Adams, who

[a] Adams, G. I., Bull. U. S. Geol. Survey No. 211, 1903, pp. 61–65. See also Adams, G. I., Carboniferous and Permian age of the red beds of eastern Oklahoma from stratigraphic evidence: Am. Jour. Sci., 4th ser., vol. 12, 1901, p. 383.

[b] Prosser, Chas. S., Revised classification of the upper Paleozoic formations of Kansas: Jour. Geol., vol. 10, 1902, table op. p. 718.

s made a special study of these conditions in Kansas, Oklahoma, d Texas. In speaking of the problem, Doctor Adams says:[a]

It appears that rocks in eastern Oklahoma, which have been referred to the d beds on lithologic grounds, are in part of Upper Carboniferous or Coal easure age. The sedimentation from the Carboniferous into the Permian an unbroken sequence. From what is known of the Permian limestones of ansas, they will be found, when followed southward, to diminish in thickess, and this change will be accompanied by a transition to more sandy eds. This is in accordance with the observations made by Mr. Gould. The age f that portion of the red beds which is in strike with the Permian of Kansas may confidently be expected to be found to be of Permian age. This is in accordance with the evidence already furnished by the vertebrate fossils. Above the Permian limestone in Kansas occur the Wellington shales, which are bluish and greenish gray in color. They are probably represented southwestward by formations which are red. The succeeding formations are typical red beds and have thus far yielded only Permian fossils. Upon the accompanying map the approximate line of transition in color has been drawn with the purpose of showing that it is diagonal to the strike of the Carboniferous and Permian formations.

Doctor Adams found the conditions in northern Texas very similar to those in the Kansas-Oklahoma region. In Young, Archer, Throckmorton, and Baylor counties, Tex., certain beds of limestone of Pennsylvania age thin out northerly and their place is taken by shales and sandstones, which become distinctly red in color. The line of change of color in the rocks cuts diagonally across the strike of the beds, very much as in northeastern Oklahoma. Doctor Adams does not attempt to draw the line between the Pennsylvanian and the Permian in either Oklahoma or Texas.[b]

From this it follows that the line of separation between Pennsylvanian and Permian rocks must be drawn far out in the red beds. If the Wreford limestone be accepted as the base of the Permian in Kansas, the location of the line of separation is a matter of the location of the Wreford in Oklahoma. This ledge is known to outcrop on Beaver Creek in the Kaw Reservation, and has been traced south by Mr. Charles A. Long across the western part of the Osage Nation to a point in the big bend of the Arkansas, about 10 miles west of Ralston and about 8 miles northeast of the mouth of Red Rock Creek, where it is striking southwest. It is probably represented south of the river in one of the ledges of limestone which are known to occur in the eastern part of Noble County, but until it is definitely located the line of separation can only be approximated. For the present, then, it will be drawn roughly through eastern Noble, western Payne, eastern Logan and Oklahoma, and western Cleveland counties, approximately paralleling the Atchison, Topeka and Santa Fe Railroad on the east as far as the vicinity of Oklahoma City, near which

[a] Adams, Geo. I., Op. cit., pp. 385–386.

[b] Adams, Geo. I., Stratigraphic relations of the red beds to the Carboniferous and Permian in northern Texas: Bull. Geol. Soc. America, vol. 14, 1903, pp. 191–200.

place it crosses that line of road and strikes South Canadian River in the western part of the Chickasaw country, west of the Arbuckle Mountains, and, if carried across Red River, will finally reach the region of the western limit of the known Pennsylvanian in Texas.[a]

DESCRIPTION OF PENNSYLVANIAN ROCKS.

If the line of separation between the Pennsylvanian and Permian rocks of Oklahoma be drawn at the line above indicated, there are in eastern Oklahoma about 5,000 square miles of Pennsylvanian rocks. In the southern part of the area these rocks are almost entirely red sandstones and clays; in the northern part they consist of alternating layers of clays, sandstones, and limestones of various colors. The line of separation between the two kinds of Pennsylvanian rocks can never be sharply drawn, for the reason stated above, that while all the rocks are in regular succession they vary in lithologic character along the strike. To express the condition more forcibly, the statement may be made that the rocks of the two sections dovetail into each other; for in the region along Arkansas River there are red shales extending northward into limestone-sandstone regions and beds of limestone extending south into the red-clay-shale country. As stated by Adams, there is an embayment of red sediments extending far to the east among Pennsylvanian strata.

For purposes of description it is proposed to divide the rocks into two districts, the names Hominy and Chandler, by which these districts will be known, being used only as convenient working terms.

Hominy district.—The Hominy district includes the area of outcrop of all the Carboniferous rocks of the Osage and Kaw reservations which lie below the Wreford limestone. The formations exposed in this district include the southern extension into Oklahoma of the Pottawatomie, Douglas, Shawnee, Wabaunsee, Cottonwood,[b] and Neosho[c] formations of the Kansas geologists and have a thickness of over 1,500 feet. In the eastern part of the Osage Nation the rocks are chiefly sandstones and shales, with some massive beds of fossiliferous limestones, while farther west, along the headwaters of Hominy

[a] During the summer of 1904, since the above was written, Mr. Charles T. Kirk, working under the direction of the Oklahoma Geological Survey, traced out the line of outcrop of the Wreford limestone south across Oklahoma. Starting on Little Beaver Creek, in the Kaw Reservation, he followed the ledge across Arkansas River and found that in Payne County the limestone disappeared and its place was taken by a ledge of sandstone to which the name Payne sandstone was applied. This ledge was traced southwest across Cimarron, Deep Fork, and North Canadian rivers, through western Lincoln, eastern Oklahoma, and central Cleveland counties. It crosses South Canadian River near Purcell. In southern Oklahoma the ledge lies some 15 to 20 miles east of the line of Pennsylvanian-Permian contact indicated on Pl. I. For full description see Mr. Kirk's paper in Third Bien. Rept. Okla. Geol. and Nat. Hist. Survey, 1904, pp. 5–1[illegible].

[b] Haworth, Erasmus, Univ. Geol. Surv. Kansas, vol. 3, 1898, pp. 91, 94.

[c] Prosser, Chas. N., Classification of the upper Paleozoic rocks of central Kansas, Jour. Geol., vol. 3, 1895, p. 797.

Creek and on Salt and Beaver creeks, the sandstones are rare, and heavy beds of cherty limestone make up the greater part of the rocks. To the south the limestones thin out, and in the vicinity of Arkansas River change into red shales.

The name Hominy is from Hominy Creek, in the southern part of the Osage country, which flows across practically all formations represented in this district.

Chandler district.—The Chandler district includes the area of outcrop of all the strata, chiefly shales and sandstones, from the eastern boundary of the red beds westward to the base of the Permian, near the line of the Atchison, Topeka and Santa Fe Railroad, including part of Pawnee, all of Lincoln and Pottawatomie, and the eastern parts of Noble, Payne, Logan, Oklahoma, and Cleveland counties. It corresponds practically to the southern continuation of the Flint Hills of Kansas and the Osage Nation, which disappear about the line of Arkansas River. Perhaps it would be more correct to say that the rocks of this district are in strike with those of the Flint Hills.

In general, the rocks of this district consist of alternating strata of red and whitish sandstone and red-clay shale. Along the streams the sandstones outcrop as ledges 20 feet or more thick, sometimes forming small waterfalls in some of the streams. To the east of the Santa Fe Railroad the sandstone beds are most abundant, but they are grayish or almost white, though the intervening clay is always red. Business blocks at Perry, Orlando, Mulhall, Guthrie, Edmond, Oklahoma City, Norman, and Noble, along the line of the Santa Fe Railroad, are built of red sandstone. The buildings of the Oklahoma Agricultural and Mechanical College, at Stillwater, and many of the business blocks at Shawnee are constructed of the lighter-colored stone. Practically all of the towns in Lincoln, Payne, and Pottawatomie counties, and those in the eastern parts of Noble, Logan, Oklahoma, and Cleveland counties, contain buildings constructed of either the red or gray sandstone. Through the entire region it is used for the abutments of bridges, for corrals and small buildings, and not infrequently for dwellings.

The sandstone is water bearing. Springs are not uncommon, and water, which is ordinarily soft and suitable for all domestic purposes, is usually found in wells at moderate depths. It is the best water found anywhere in the red beds below the Quartermaster formation.

The region is well wooded. Trees grow along the streams and in many places on the hills. The three eastern counties, especially, are covered with a considerable growth of the more hardy forest trees, notably oak and hickory. Along the line of the Santa Fe

Railroad the uplands are level prairie and the bottom lands are timbered. West of this line the timber becomes less plentiful.

While fossils are not particularly common in the Chandler district, still a number of localities have been found which yield typical Pennsylvanian invertebrates. Near Chandler, the county seat of Lincoln County, for which the district is named, the following forms were found: *Allorisima subcuneata*, *Pinna peracuta*, *Spirifer cameratus*, *Meekella straticostata*, *Productus semireticulatus*, and *Athyris subtilita*.

PERMIAN SERIES.

PERMIAN ROCKS OF KANSAS.

According to the classification of the Kansas geologists, notably Prosser, the line of separation between the Carboniferous and Permian in Kansas has been drawn at the base of the Wreford limestone, a ledge typically exposed near Junction, Kans., on Kansas River.[a] In southern Kansas this ledge outcrops near the summit of the Flint Hills in eastern Cowley County and along Grouse Creek, near Dexter, and, as stated above, is found in Oklahoma along Little Beaver Creek, in the Kaw Reservation, and in the western part of the Osage Nation as far south as Arkansas River. Above the Wreford limestone in southern Kansas and eastern Kay County, Okla., there are at least three heavy beds of limestone with interbedded shales, known as the Florence flint, Fort Riley limestone, and the Winfield formation. Above the Winfield formation limestones become less prominent and clays and shales make up the greater part of the series. These formations above the limestone members constitute the Marion formation of Prosser and the Wellington shales of Cragin.[b] In general, both the Marion and Wellington formations consist of gray, blue, drab, and yellowish shales with a few ledges of impure limestone. The extensive salt beds in central and southern Kansas and the deposits of gypsum in several counties of Kansas and in Kay County, Okla., are found in these rocks. These two formations, however, appear not to be sharply defined, and inasmuch as both consist of rocks of essentially the same character a definite line of separation will probably not be drawn between them, and it is not impossible that as a result of more exact knowledge of the conditions both formations will finally be grouped together.

[a] Prosser, Chas. S., Revised classification of the upper Paleozoic formations of Kansas Jour. Geol., vol. 10, 1902, p. 703.

[b] See articles by Professor Prosser, Jour. Geol., vol. 8, 1895, pp. 764–796; and by Professor Cragin, Colorado Col. Studies, vol. 6, 1896, pp. 8–18.

The southern extension of the Marion and Wellington formations, as well as the southern part of the Flint Hills, reach from Kansas into Oklahoma. The Flint Hills, as stated above, occupy the western part of the Osage Nation, all of the Kaw Reservation, and the eastern part of Kay, Noble, and Pawnee counties. The southern extensions of the Marion and Wellington occur in western Kay County and pass into the Ponca and Otoe reservations, occupying a triangular area between the Flint Hills and the red beds. A glance at the map (Pl. I) will reveal the fact that these formations narrow rapidly in northern Oklahoma and their place is taken by the red beds. Perhaps it is more correct to state that the color of the shales changes to the south, becoming red, while at the same time more of the red sandstone comes in, so that finally the formation changes to typical red beds. On the State line the distance from the Winfield formation, the upper conspicuous limestone member, to the eastern outcrop of the red beds is perhaps 30 miles; on the southern line of Kay County, Okla., it is not more than 15 miles, while farther south the line of separation can not be determined, for the reason that the limestone disappears and its place is taken by red shales and sandstones. In southern Kansas there are three distinct kinds of Permian rocks: First, the heavy limestones in eastern Cowley County and along Walnut River; second, the bluish and gray clays and shales of the Marion and Wellington formations from Walnut River to western Sumner County; and third, the typical red beds consisting of red sandstones and clays extending from this point nearly to the west line of the State. In eastern Oklahoma, on the other hand, only the red beds appear.

Thus it is seen that the red beds extend farther east in Oklahoma than in Kansas, and that the eastern limit of the red beds does not coincide with the line of separation between the Pennsylvanian and Permian. In other words, the red color of the rocks, which has been thought characteristic of only the Permian of the region, in fact transgresses far into the region of the Pennsylvanian rocks. This means, of course, that the line of separation between the rocks of these two epochs must finally be drawn far out in the red beds, and this the writer has attempted to do.[a]

GENERAL RELATIONS OF PERMIAN ROCKS IN OKLAHOMA.

Permian rocks, usually known as the "red beds," occupy the greater part of Oklahoma. This series of rocks is by far the most important in the Territory, inasmuch as it is not only the origin of nearly all the soils, but it also supplies most of the building stone, gypsum,

[a] See footnote, p. 32.

salt, and other economic products, and at the same time furnishes the water supply for the greater part of the Territory. These rocks have been studied for a number of years both in Kansas and Texas, and considerable literature has accumulated upon the subject,[a] but no attempt has ever been made to write a description of the red beds as a whole, nor is such a task contemplated here. All that is attempted is, first, to give only such references as will enable the reader to understand former classification, and afterwards to present a classification, based upon the results of several years field work, that is believed to embody such conditions as exist in Oklahoma.

The geological age of the red beds has long been an open question. The reason for this uncertainty has always been a lack of fossils, for until within the past few years organic remains had been found in but one or two localities in the Oklahoma red beds, and in Kansas none at all. Recently, however, fossils, both vertebrates and invertebrates, all of Permian age, have been discovered in at least five general localities in the red beds of Oklahoma. It seems reasonably certain, however, as shown by Adams,[b] that a large part of the typical red beds rocks in eastern Oklahoma are really Pennsylvanian in age, and, on the other hand, since fossils are not at the present time known to exist in the higher members of the series, the age of that part of the red beds is still open to doubt. And, moreover, until the correlation with the Texas red beds has been more fully worked out and fossils collected and identified throughout the entire region the matter can not be considered as settled. Instead of using any strictly geologic term in speaking of the rocks of the series the writer will employ the name of "red beds," by which the rocks are generally known, to include the rocks of both the Pennsylvanian and Permian ages, it being understood that the rocks above the lower part of the Enid formation are regarded as Permian in age and those below this point as Pennsylvanian.

The red beds area of the southern part of the Great Plains extends for 600 miles or more across Kansas, Oklahoma, Indian Territory, Texas, and New Mexico. The most northern exposure of the beds, so far as known to the writer, is near Arlington, a few miles south of Hutchinson, Reno County, Kans. To the southwest they pass under the Tertiary of the High Plains, or Llano Estacado, and appear in the valleys of the Pecos and Rio Grande in New Mexico.

The eastern border of the outcrop of the red beds in Kansas and Oklahoma is a crescent-shaped line running southeast from near Hutchinson and east of Kingman, Kans., crossing the Kansas-Oklahoma line at Caldwell, then trending southeast near Nardin,

[a] See under "Classification."

[b] Loc. cit.

Tonkawa, and Red Rock, cutting diagonally across the strike of Pennsylvanian limestones and shales through the eastern parts of Payne and Lincoln counties to the western part of the Creek and Seminole nations. Here the line swings to the southwest and continues through the Chickasaw Nation to the vicinity of Davis, Ind. T., passes around the western end of the Arbuckle Mountains, crossing Red River 35 miles west of Gainesville, Tex., and, as stated by Adams, cuts diagonally across the strike of Pennsylvanian rocks in Archer, Young, and Throckmorton counties, Tex.[a] Wherever exposed, the rocks of this series along their eastern border merge into the Pennsylvanian limestones and shales.

The western limit of the red beds in Oklahoma and Kansas is much more irregular. In all instances, so far as observed, the upper line is one of unconformity. The superjacent rocks range from the Lower Cretaceous to those of the latest geologic formations, but by far the greater part of the overlying deposits are of the later Tertiary age. In places the Tertiary deposits extend east along some divide nearly across the red beds area. In other localities they have been almost removed by erosion and the red beds are exposed far to the west of the main body. Along the valleys of the larger streams the red rocks reach many miles westward, although the level uplands are covered by the Tertiary beds. The South Canadian, for instance, has cut through the Tertiary deposits for practically its entire course across the plains, and red beds are everywhere exposed. Other streams, including the Salt Fork, Cimarron, North Canadian, Washita, and Red rise in the Tertiary deposits west of the red beds and flow southeast across these beds and pass into the Pennsylvanian area to the east. It is along the course of these rivers that some of the finest exposures of the red beds may be seen.

CLASSIFICATION.

The red beds in Texas were described by Professor Cummins[b] in 1891. He divided the series into the Wichita beds, the Clear Fork beds, and the Double Mountain beds. In 1902 Professor Hill proposed the term "Brazos series" to apply to the red beds as a whole[c] Professor Cragin has published two papers on the red beds of Kansas and Oklahoma. In his first paper, published in 1896,[d] the red beds were designated the Cimarron series in contradistinction to the Big

[a] Op. cit., p. 196.

[b] Cummins, A. W., Second Ann. Rept. Geol. Survey Texas, 1891, pp. 394–424.

[c] Hill, Robert T., Geology and geography of the Black and Grand prairies, Texas: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 7, 1901, p. 100.

[d] Cragin, F. W., The Permian system in Kansas: Colorado Col. Studies, vol. 6, 1896, p. 3.

Blue series or lower Permian, and the Permian rocks were divided as follows:

- Cimarron series
  - Kiger division
    - Big Basin sandstone.
    - Hackberry shales.
    - Day Creek dolomite.
    - Red Bluff sandstone.
    - Dog Creek shales.
  - Salt Fork division
    - Cave Creek gypsums.
    - Flowerpot shales.
    - Cedar Hills sandstones.
    - Salt Plain measures.
    - Harper sandstone.
- Big Blue series
  - Sumner division
    - Wellington shales.
    - Geuda salt measures.
  - Flint Hills division
    - Chase limestones (Prosser).
    - Neosho shales (Prosser).

Professor Cragin afterwards adopted Prosser's name, Marion, instead of Geuda salt measures. In a subsequent paper Professor Cragin modified his classification of the Cimarron as follows:[a]

- Kiger
  - Taloga ..... Quite variable with locality.
  - Day Creek ..... None.
  - Red Bluff ..... None determined.
- Salt Fork
  - Dog Creek (Stony Hills)
    - Chapman dolomite.
    - Amphitheater dolomite.
  - Cave Creek
    - Shimer gypsum.
    - Jenkins clay.
    - Medicine Lodge gypsum.
  - Glass Mountain
    - Flowerpot shales.
    - Cedar Hills sandstone.
  - Kingfisher
    - Salt Plain.
    - Harper.

The writer has spent four seasons in studying the red beds of Oklahoma and finds that there are local conditions which make it desirable to propose a somewhat different classification from any previously suggested. The writer has used the earlier classifications as far as they can be applied, and he has adopted the names which are equivalent to those that he recognizes, but where new classification has become necessary he has given new names to avoid confusion of terms.

The following table shows the relation of Professor Cragin's revised classification to the one used in this report:[b]

[a] Cragin, F. W., Observations on the Cimarron series: Am. Geologist, vol. 19, 1897, pp. 351–363.

[b] See article by the writer in Second Bien. Rept. Oklahoma Geol. and Nat. Hist. Survey, 1902, pp. 42 et seq.

Relations of classifications of Permian rocks.

Cragin's classification.	Classification used in this report.	
	Quartermaster formation.	
Taloga	Greer formation	Mangum dolomite member. Collingsworth gypsum member. Cedartop gypsum member. Haystack gypsum member. Kiser gypsum member. Chaney gypsum member.
Day Creek Red Bluff Dog Creek (Stony Hills)	Woodward formation	Day Creek dolomite member. Whitehorse sandstone member. Dog Creek shales member.
Cave Creek	Blaine formation	Shimer gypsum member. Medicine Lodge gypsum member. Ferguson gypsum member.
Glass Mountain Kingfisher	Enid formation.	

The term "formation" is here used in a general sense to designate a larger or smaller sequence of strata, which in one instance corresponds to a formation having a simple and uniform lithologic character, or in another, to a group of such formations. The classification is intentionally elastic, since the precise stratigraphic relations, which could be determined only with accurate base maps and detailed surveys, have not yet been ascertained. The generalized section shown in fig. 2 represents graphically the classification used in this report.

ENID FORMATION.

The Enid formation includes all the rocks of the red beds from the base of the Permian to the lowermost of the gypsum ledges on the eastern slope of the Gypsum Hills. The top of this formation, however, is not a plane, since the gypsum beds, which mark its uppermost limits, are found to be more or less lenticular when traced for long distances. The Enid comprises all of the Harper, Salt Plain, and Cedar Hills members and the greater part of the Flowerpot member of Cragin's first paper and the Kingfisher and Glass Mountain formations of his second paper. It is named from the county seat of Garfield County.

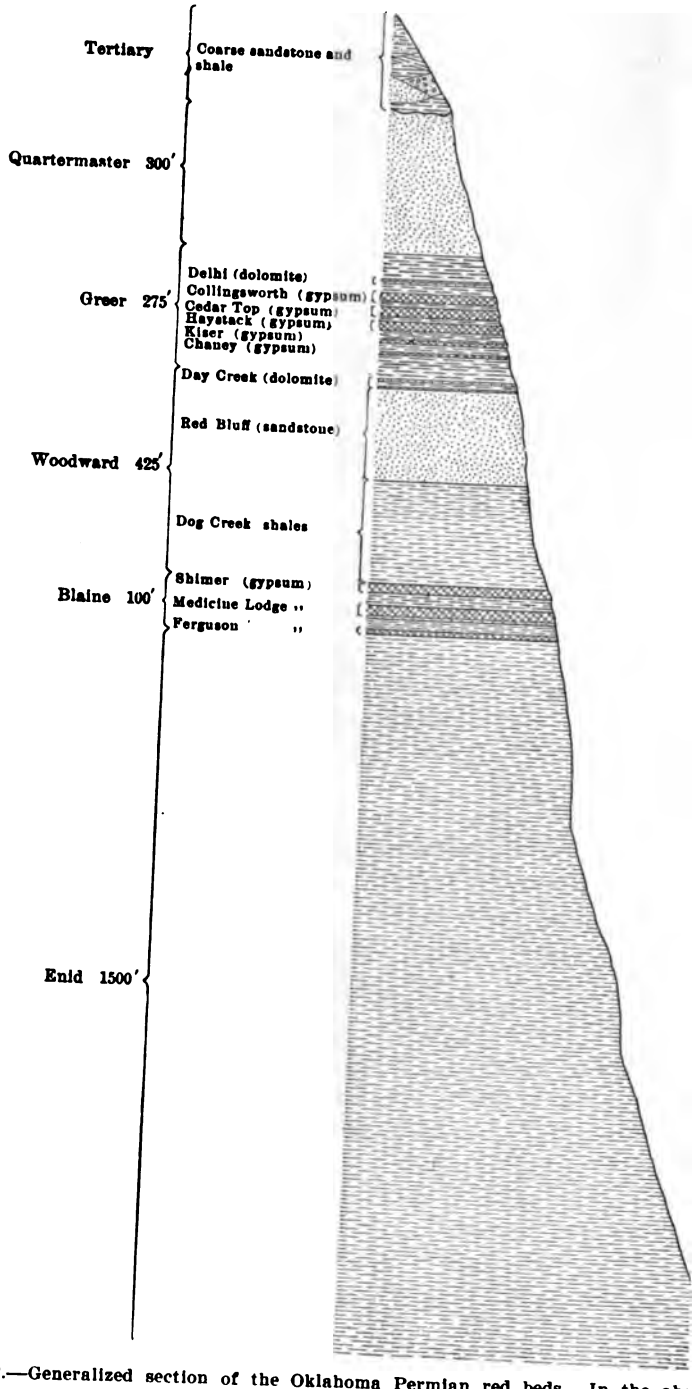


FIG. 2.—Generalized section of the Oklahoma Permian red beds. In the ab
"Delhi" should read Mangum and "Red Bluff" Whitehorse.

The Enid outcrops over a larger area than any other formation of the Permian in Oklahoma and is exposed extensively in adjoining States. In Kansas it outcrops over parts of Sumner, Kingman, Reno, Barber, and Comanche counties and all of Harper County. In Oklahoma it is found in the western parts of Kay, Noble, Payne, Logan, Oklahoma, and Cleveland, parts of Woods, Woodward, Blaine, and Canadian, and all of Kingfisher, Garfield, and Grant counties. It also extends into the Chickasaw Nation.

The Enid formation consists chiefly of brick-red clay shales, with some interbedded ledges of red and whitish sandstone. It occurs in two general areas, which may be distinguished on lithological grounds as follows: An eastern area, in which there are a few inconspicuous ledges of sandstone, and a western area, in which the sandstones are mostly wanting. In the present state of knowledge it is impossible to draw an accurate line of separation between these two areas, and for this reason the strata in them are not defined as separate members.

The eastern area of the Enid formation is triangular and occupies several counties in the central part of the Territory, in which there is little hard rock of any kind. Its eastern boundary is approximately along a line from Blackwell to Norman and its western limit is along a line from Alva to El Reno. It includes eastern Blaine, Canadian, and Woods counties, all of Grant, Garfield, and Kingfisher, and the western parts of Kay, Noble, Logan, Oklahoma, and Cleveland counties.

Throughout this area the soil is red, except where later deposits cover the uplands or among the sand hills north of some of the streams. Red clays and occasional ledges of thin sandstone outcrop along the bluffs of a few streams. These sandstone ledges, however, are of comparatively little economic value, being generally too soft for building purposes. Quarries occur near Nardin, Kingfisher, Hennessey, and Luella. In the general absence of building stone, foundations for houses are usually made of brick, and artificial stone may come into use extensively.

The rocks of the western area of the Enid consist chiefly of red clay shale, some inconspicuous ledges of soft sandstone, and occasional bands of whitish or greenish shales, which vary from 1 inch to several feet in thickness. The upper strata are in places highly gypsiferous, and at some localities brine springs issue from them. No attempt is made to separate the eastern and western areas of the Enid formation, except to state that they are sometimes separable locally a few miles east of the base of the Gypsum Hills.

The Enid formation is in most places strongly impregnated with mineral salts, particularly common salt and gypsum. In many localities the water from the wells is unfit for drinking, and the people are obliged to use cistern water.

In the western area, along the base of the Gypsum Hills, salt measures are prominent. The Little Salt Plain, in northern Woodward County, near the Kansas line, and Big Salt Plain, in the northeastern part of the same county, are both located in the Cimarron channel, while the Salt Creek Plain, in north-central Blaine County, is on a tributary of the same river. At the Salt Creek Plain some of the most typical saline springs in the Territory may be seen. In several canyons at the head of Salt Creek are exposures of a grayish-red, mottled, saliferous sandstone. This sandstone is often distinctly cross-bedded, and appears to have been tilted; from it issue numerous springs of strong brine. So far as known, this sandstone is not found elsewhere in the region, and it seems to be a local phase of the clay-shale formation. It is possible, however, that these sandstones are not themselves salt bearing, but are merely porous strata through which brines from some deep-seated source reach the surface. The water from the springs issuing from the various canyons forms rills, which, in turn, unite to form the headwaters of Salt Creek.

Above the level of the Salt Plains and below the gypsum ledges there intervene 150 or 200 feet of red clay shale, which is interspersed with bands of whitish, greenish, and bluish clay and local thin ledges of gypsum.

The following analyses of shales from the slope of the Gypsum Hills indicate their chemical constitution:

Analysis of clay from Stucks Canyon, at the head of Salt Creek, 4 miles west of Ferguson, Blaine County, Okla.

	Per cent
Silica	64.1
Calcium oxide	1.3
Iron oxide	8.1
Aluminum oxide	14.[illegible]
Magnesium sulphate	5.[illegible]
Magnesium carbonate	.[illegible]
Water	6.[illegible]
Total	100.[illegible]

Analysis of so-called copper ore from Henquencts Canyon, on Salt Creek, 4 miles east of Ferguson, Blaine County, Okla.

	Per cent
Silica and insoluble silicates	67.4
Iron oxide	16.9
Calcium carbonate	1.8
Magnesium carbonate	5.4
Sodium chloride	4.9
Water	3.4
Total	100.0

The material analyzed was a concretion-like piece of green clay or shale. It is thought by some to be copper ore, on account of its color

A. TYPICAL RED-BEDS EROSION.

B. RED-BEDS SLOPE BELOW MASSIVE GYPSUM.

but it contains no copper, and the green color is due to some form of iron, probably a mixture of ferrous and ferric oxides.

Analysis of gypsiferous green clay from slope of the Gypsum Hills, near Mount Heman, eastern Woodward County, Okla.

	Per cent.
Calcium sulphate	58.06
Calcium carbonate	5.35
Magnesium carbonate	3.49
Water	15.38
Oxides of iron and aluminum	3.27
Silica and insoluble residue	13.58
Total	99.13

The very soft material of which this shale is composed renders it particularly susceptible to the action of weathering and the entire thickness is characterized by such marked erosion forms as are shown on Pl. VII, *B*. Wherever the cap of gypsum has been removed over any considerable area, or for any great length of time, these shales have been worn away. Perhaps the most common erosion form is that of cones of red clay cut by deep and uneven gullies—regular badlands structure. Not infrequently rows of these cones are arranged palisade-like along the summit of a fast-disappearing ridge into which gullies are eating their way (Pl. VII, *A*.) In the Glass Mountains, for instance, the slope of the bluffs below the gypsum ledges is much cut by erosion. The action of the water has produced a great variety of unusual forms; small buttes and buttresses, cones and minarets, pinnacles and peaks, shoulders and ridges, domes, towers, chimneys, gullies, ravines, and all sorts of fantastic shapes have been carved by erosion from the blood-red shales along the slope of the bluffs.

The face of the bluffs is frequently covered with fragments of gypsum, either in the form of plates of transparent selenite (Pl. VIII, *B*) or in the form of concretionary masses (Pl. VIII, *A*). The selenite is usually found in seams running diagonally through the clay, and the crystals weather out and reflect the sun from thousands of points, making the slopes appear to be covered with glass, whence the name Glass Mountains.

An analysis of two specimens of the transparent selenite and one of the concretionary masses is given below.

Analysis of a thin ledge of satin spar from the canyon ¼ miles west of Ferguson, Blaine County, Okla.

	Per cent.
Calcium sulphate	78.87
Water	20.94
Insoluble residue	.18
Total	99.99

Analysis of selenite flakes from Mount Heman, eastern Woodward County, Okla.

	Per cent.
Calcium sulphate	76.76
Magnesium carbonate	.84
Water	19.80
Iron and aluminum oxides	1.45
Insoluble residue	.95
Total	99.80

Analysis of crystalline gypsum concretions from Henquenets Canyon, 4 miles west of Ferguson, Okla.

	Per cent.
Calcium sulphate	75.20
Magnesium carbonate	1.56
Water	17.32
Oxides of iron and aluminum	2.52
Insoluble residue	4.54
Total	100.89

The thickness of the Enid formation is unknown, but it is probably not less than 1,200 feet, and may reach 1,500 feet. The well at Fort Reno, a section of which is shown in Pl. XXII, was started at about the same level as the top of this formation and reached a depth of 1,370 feet, the drill stopping in red clay. It is possible, however, that this well passed through the Permian rocks into red beds of Pennsylvanian age beneath. At Spencer, 12 miles east of Oklahoma City, a well passed out of the red beds at a depth of 1,550 feet. The greater part of this thickness, however, was in Pennsylvanian rocks.

BLAINE FORMATION.

The Blaine formation consists of red shales with interbedded strata of gypsum and thin ledges of dolomite. It includes the portion of Professor Cragin's Flowerpot formation above the base of the Ferguson gypsum and all of his Cave Creek formation. It is named from Blaine County, Okla., where it is typically developed.

The characteristic which justifies its recognition as a formation is the abundance of gypsum contained in it, and its extent and limits are defined accordingly. The bottom of the lowest massive gypsum bed—the Ferguson gypsum member—is the base of the formation throughout its occurrence northwest from Darlington, Canadian County. Where it disappears the shales of the Enid continue up to the base of the Medicine Lodge gypsum member, which necessarily becomes the basal member of the formation. The top is the Shimer gypsum member. Where the gypsum members run out, as they also do north of Darlington, the Blaine can not be distinguished readily

A. GYPSUM CONCRETIONS COVERING THE SLOPES OF RED CLAY, GLASS MOUNTAINS.

B. SELENITE AND SATIN SPAR IN RED CLAY.

from the Enid below and the Woodward above, and this local division of the red beds can not well be traced. The Blaine formation gives rise to an escarpment known as the Gypsum Hills, extending from Darlington northwestward between North Canadian and Cimarron rivers, through the corner of Kingfisher County, across Blaine County into Woods County. At the Glass Mountains the escarpment approaches closely the Cimarron, which it parallels northwesterly to the Kansas boundary. Beyond Cimarron River the gypsum beds are exposed in the northwestern corner of Woods and pass into Barber County, Kans., where they trend north and northwest and finally disappear under the Tertiary sands north of Medicine River, 30 miles northwest of Medicine Lodge.

From the east the Gypsum Hills appear as a wall crowned with a

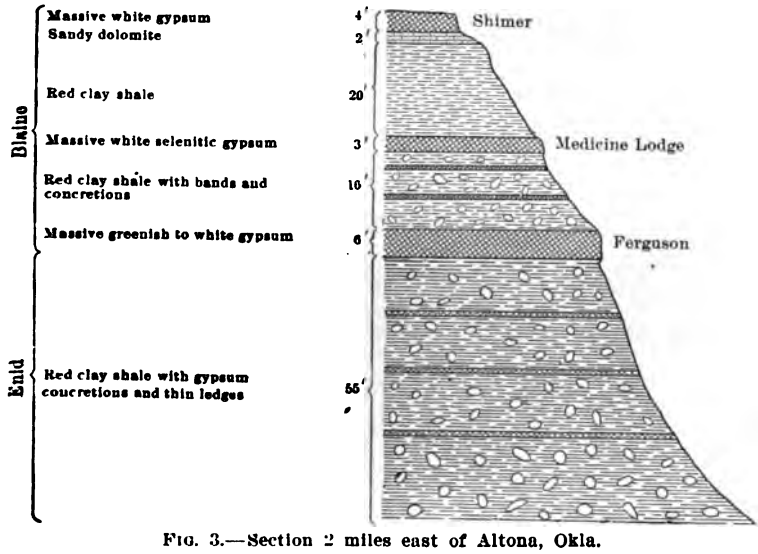


FIG. 3.—Section 2 miles east of Altona, Okla.

white band, but the sky line is not continuous, as numerous breaks occur where the gypsum ledge has been dissolved by water and carried away. The general appearance is rather that of an uneven row of flat-topped buttes or mesas of various sizes than a single hill with a continuous escarpment. To these buttes the name "Mansard Mounds" has been given by one writer, in fancied resemblance to a mansard roof.[a] Not infrequently a few bold points stand out at a distance east of the main range, and these outliers being more conspicuous have sometimes received distinct names, as Glass Mountains, Mount Heman, Cedar Hill, and Henquenets Butte. Particular names have been given to certain parts of the range, as Stony Hills, in Blaine County, east of Watonga, and Chatauqua Mountains for

[a] Hay, Robert, Bull. U. S. Geol. Survey No. 57, 1890, p. 22.

the same range farther north, extending to the Glass Mountains. The name Marcy Range has been proposed for the entire section of hills. These names, however, probably will never supersede the much-used term, "Gyp Hills."

The Blaine formation consists of three ledges of massive gypsum interstratified with red shale and an occasional local ledge of more or less arenaceous and argillaceous dolomite, which usually occur at the base of the heavy gypsum. Only the gypsum members will be described in this report. The shales which make up the greater part of the red beds have not been differentiated and the dolomites

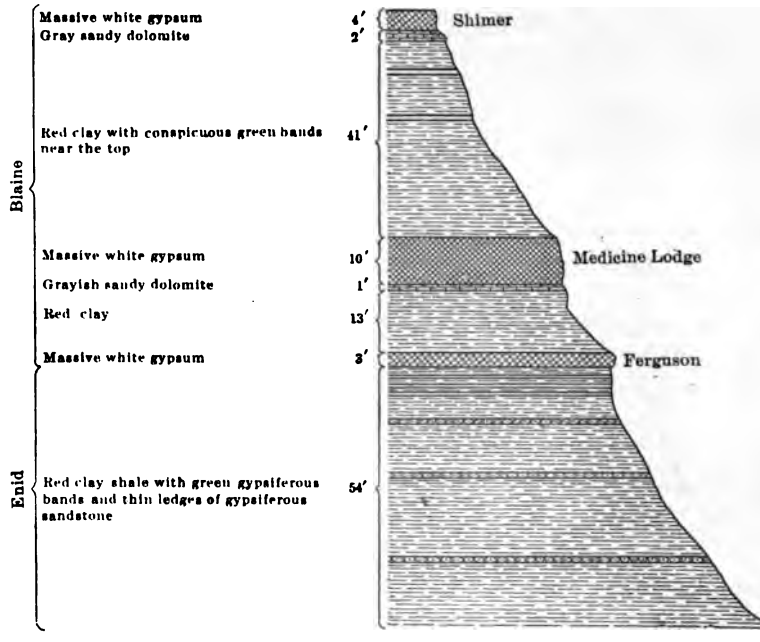


FIG. 4.—Section near Watonga, Okla., in sec. 32, T. 16 N., R. 10 W.

are too local to deserve formation rank. The gypsum members of the Blaine are briefly described below.

Ferguson gypsum member.—The Ferguson gypsum member is the lowermost of the thick gypsum beds in the red beds of this region. It varies in color from almost pure white to a dirty brown, according to the purity of the mineral. It outcrops usually a little more than half way up the slope of the escarpment formed by the formation, but is rarely conspicuous. In Canadian, Kingfisher, and southern Blaine counties it is the thickest of the three gypsum members, but it thins out to the north and disappears in the region of the Glass Mountains, north of which only the two upper gypsum ledges appear. The name is derived from the town of Ferguson, Blaine County, in

the hills southwest of which the ledge is typically exposed. The following is an analysis of this ledge:

Analysis of gypsum from 4 miles west of Ferguson, Okla.

	Per cent.
Calcium sulphate	80.09
Water	19.82
Insoluble residue	.65
Total	100.56

On Pl. IX, *A*, the Ferguson is the lowermost of the gypsum members, scarcely distinguishable as a white line halfway up the slope. Its relation to the other gypsum members is shown in fig. 5.

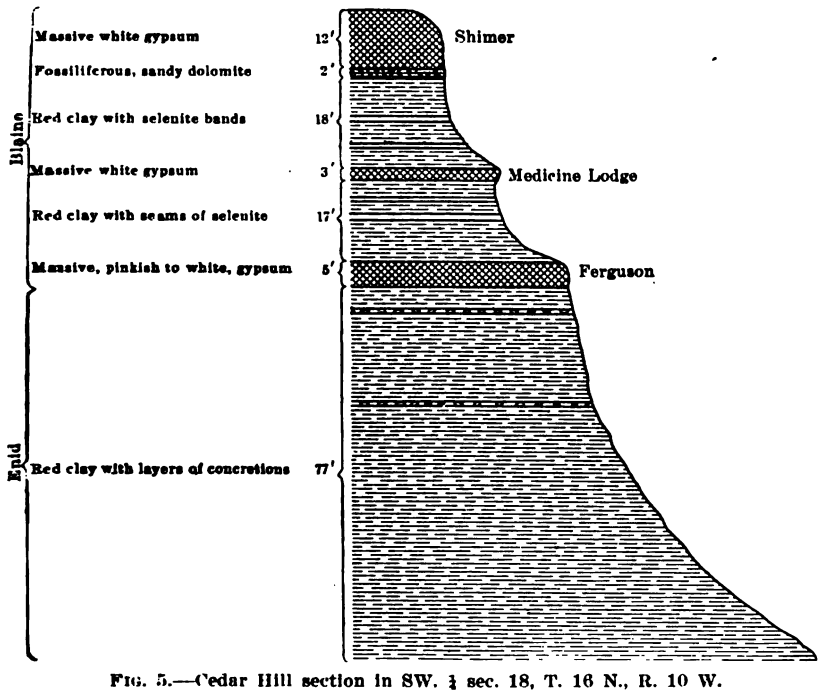


FIG. 5.—Cedar Hill section in SW. ¼ sec. 18, T. 16 N., R. 10 W.

Medicine Lodge gypsum member.—The Medicine Lodge gypsum is the most conspicuous gypsum deposit in the red beds. It extends uninterruptedly from near the head of Medicine River, in Kansas, to Canadian County, Okla., and is in most places the ledge which forms the cap of the Gypsum Hills. Perhaps no better description of this ledge can be given than that of Professor Cragin, who first described it in Kansas, as follows:[a]

In minor parts, the Medicine Lodge gypsum is nearly pure white; in others it is suffused with leaden-gray or dusky-brown shades; most commonly it is

[a] Cragin, F. W., The Permian system in Kansas: Colorado Col. Studies, vol. 6, 1896, p. 32.

grayish white mottled with feebly defined dark spots. The latter are generally the expression of a tendency that existed in the gypsum to form crystals under the original conditions of a precipitation, as is shown by the occurrence of spots in every gradation from ill-defined spot-like segregations to well-formed crystals of selenite. Some of the crystals are of the common rhomboidal pattern, others are of the stellar type.

In the region around the head of Salt Creek and its tributary, Bitter Creek, in Blaine County, Okla., the Medicine Lodge gypsum,

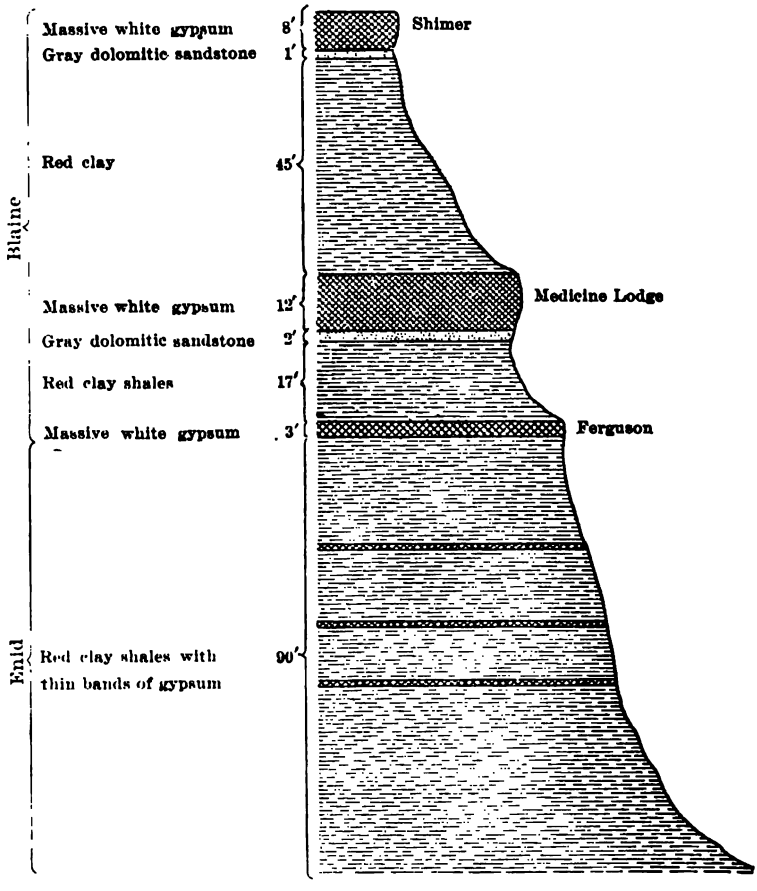


FIG. 6.—Hitchcock section 4 miles south of Hitchcock, Okla., along Rock Island Railroad.

the middle of the three ledges, has a peculiar form. The middle part of the ledge, usually 8 to 10 feet thick, is much harder than the rest of the bed or any other ledge of gypsum known in the Territory. As seen from below, this part of the ledge is pure white, as shown on Pl. IX, *B*. It breaks with an even fracture, so that it may often be distinguished a mile away. On closer examination it is found to be very hard and very fine grained, usually pure white, but with an occasional bluish

A. CEDAR HILL, EAST OF WATONGA, OKLA.

Showing Ferguson gypsum on the slope and Medicine Lodge gypsum as a cap.

B. ANHYDRITE MEMBER OF THE MEDICINE LODGE GYPSUM.

Salt plain in foreground.

or reddish tint. It takes a good polish and has the general appearance of marble, and is known locally as the Salt Creek marble. And sometimes it is difficult to persuade farmers who own a part of the ledge that the rock is not valuable for building stone or for ornamental purposes. A chemical analysis reveals the fact that the rock approaches an anhydrite—that is, it has a very small per cent of water of crystallization. Ordinary gypsum contains from 20 to 21 per cent of water, while in the rock from this ledge the amount of water is sometimes as low as 2 per cent.

The area covered by the anhydrite is about 10 miles long and 1 mile or more wide. No adequate explanation of this peculiarity of structure has ever been forthcoming. It is probably because of this relatively harder ledge, which resists erosion, that the marked topographic forms mentioned above are due.

The following analyses show the relatively small amount of water in this rock:

Analyses of "marble" gypsum from the middle part of the Medicine Lodge member.

	Per cent.	Per cent.
Calcium sulphate	94.83	92.73
Magnesium sulphate	1.93	------
Magnesium carbonate		3.15
Water	2.74	3.15
Insoluble residue		.33
Total	99.50	99.36

Analysis of "red marble" gypsum from the middle part of the Medicine Lodge member.

	Per cent.
Calcium sulphate	84.00
Calcium carbonate	3.41
Magnesium carbonate	2.13
Water	5.38
Oxides of iron and aluminum	.78
Insoluble residue	1.69
Total	97.39

The analyses given below indicate the composition of the gypsum from the lower, middle, and upper parts of the Medicine Lodge:

Analyses of gypsums from the lower (1), and middle (2 and 3) parts of the middle ledge of the Medicine Lodge member.

	Per cent.	Per cent.	Per cent.
Calcium sulphate	79.66	94.94	80.82
Water	20.22	4.95	20.89
Insoluble residue	.46	.67	.35
Total	100.34	100.56	102.06

No. 1 is very hard, being almost an anhydrite, and is left in la bowlders when the softer parts are worn away. No. 2 is softer sometimes fills the place usually occupied by No. 1.

Analyses of gypsums from the upper part of the Medicine Lodge membe

	1. Per cent.	2. Per cent.	Per
Calcium sulphate	78.41	78.23	8
Magnesium carbonate	2.03	.98	
Oxides of iron and alumium	1.38	------	--
Water	18.23	20.75	
Insoluble residue	.41	.34	
Total	100.46	100.30	1(

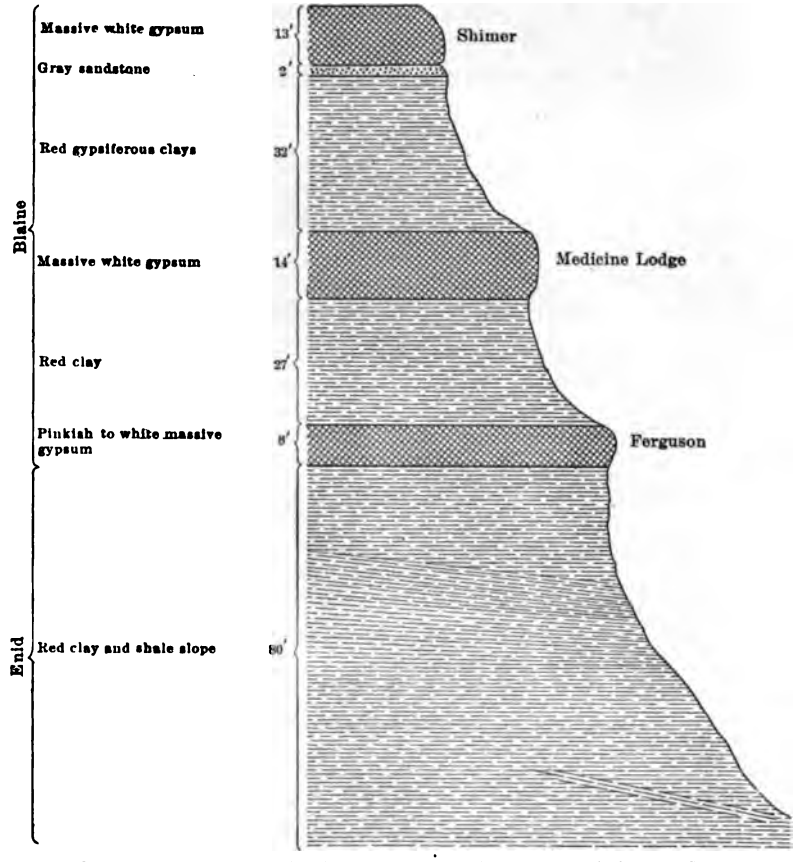


FIG. 7.—Bitter Creek section, 6 miles southwest of Ferguson, Okla., on West Bran Bitter Creek.

Nos. 1 and 2 are the rocks that make up the greater part of ledge and are used for plaster. No. 3 is harder material, approacl anhydrite, sometimes found in lumps or masses, and is not used plaster.

The name Medicine Lodge is that of the county seat of Barber County, Kans., and was proposed by Professor Cragin in 1896.

Shimer gypsum member.—A third gypsum ledge, to which Professor Cragin gave the name Shimer gypsum, from a township in Barber County, Kans., where the rock was first studied, is the uppermost member of the Blaine formation. It is typically exposed either as the highest gypsum outcrop somewhat back from the brow of the hills, or as the cap rock of occasional bluffs and buttes overlooking

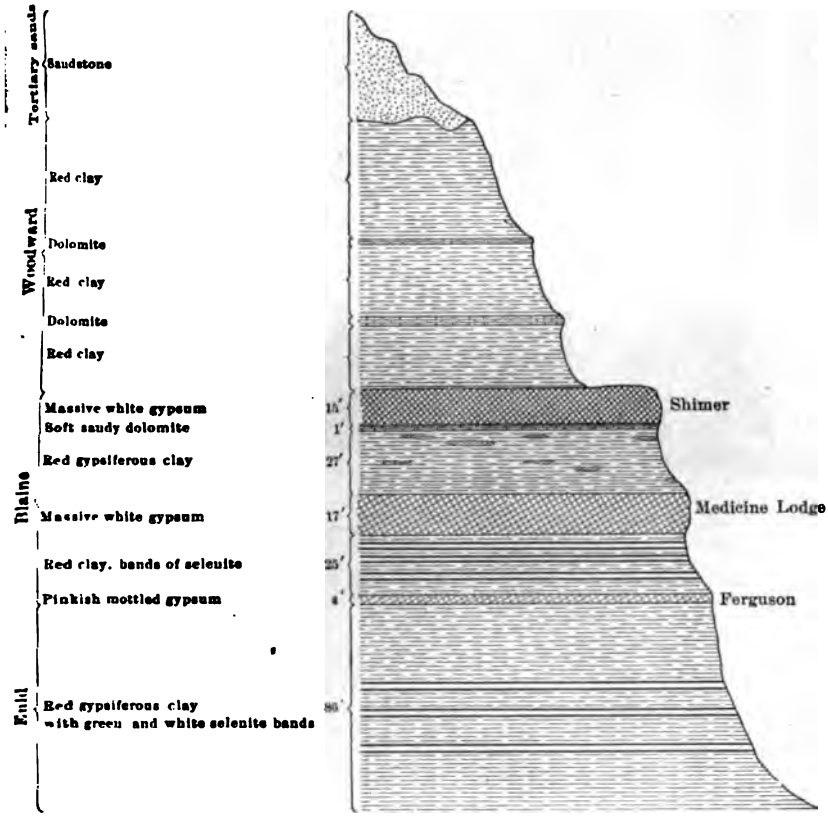


FIG. 8.—The Rubey section, in South Canyon, head of Salt Creek, at the Rubey stucco-plaster mill, Ferguson, Okla.

he slopes below. It is the upper white ledge shown in Pls. IX, *B*, nd XXI, *A*. The description of the Medicine Lodge gypsum noted above from Professor Cragin will in most places apply equally well to the Shimer, but the thickness of the upper ledge is not so reat as that of the Medicine Lodge. Its areal extent and physical haracters are about the same, except that so far as known there is o anhydrite in the Shimer.

The following analyses, made from specimens obtained from the

Shimer member of the Blaine formation in the canyons 4 miles west of Ferguson, indicate the constituents of this rock:

Analyses of gypsum from the lower (1), middle (2), and upper (3) parts of the Shimer member.

	1. Per cent.	2. Per cent.	3. Per cent.
Calcium sulphate	78.22	80.16	79.07
Water	21.22	20.00	21.00
Insoluble residue	.87	.86	.39
Total	100.31	101.02	100.46

In some localities the shale member which separates the Medicine Lodge from the Shimer thins out and the two massive gypsum ledges are practically continuous. Caves are not uncommon below the various ledges. A generalized section of one of these caves is shown in fig. 9.

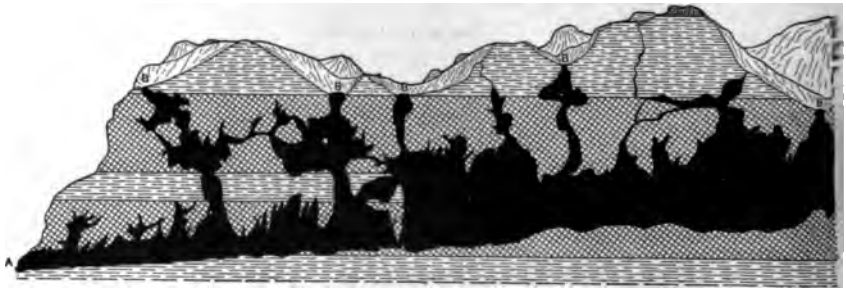


FIG. 9.—Section of gypsum cave.

The thickness of the Blaine formation varies considerably with the locality, but it averages about 75 feet.

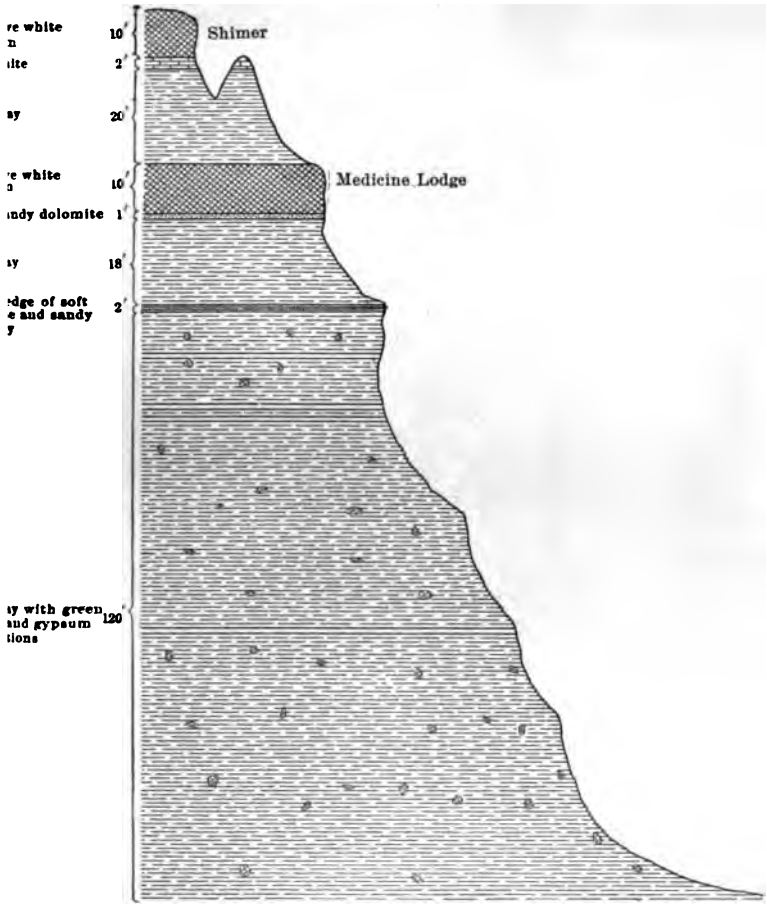
WOODWARD FORMATION.

Above the Blaine is approximately 300 feet of rocks, consisting chiefly of shales, sandstones, and dolomites, and distinguished from the formations above and below by the prominence of dolomites and the absence of gypsum. The formation includes all the rocks between the two conspicuous gypsum horizons, the Blaine and the Greer, and in general it may be divided into three members—the Dog Creek, the Whitehorse and the Day Creek—which were all recognized and named by Professor Cragin from localities in Kansas, except that his term Red Bluff was preoccupied, and for it the name Whitehorse has been substituted. For the formation as a whole, from the top of the Shimer gypsum to the base of the Chaney gypsum, the name Woodward is proposed, from the county in Oklahoma where the strata are well represented.

Dog Creek shales member.—The Dog Creek member is composed

' of clays, containing occasional thin ledges of magnesian lime-
which in places grade into a fair quality of dolomite.
ledges, however, are usually thin and rarely sufficiently con-
us to be worthy of more than passing notice. Professor Cra-
riginal description of this member is as follows:[a]

Dog Creek * * * consists of some 30 feet, or locally of a less or
thickness, of dull-red argillaceous shales, with laminæ in the basal



'IG. 10.—Roscoe section, 1 mile south and 1½ miles west of Roscoe, Okla.

d one or two ledges of unevenly lithified dolomite in the upper. The
' these shales resembles that which prevails in most of the divisions
ther than of the terranes above the Dog Creek.

is second paper he modifies his description in this way:

ntral Oklahoma it is a great dolomite formation, laminated dolomite
ng a considerable part of the thickness.[b]

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lt., p. 39.
n, F. W., Observations on the Cimarron series: Am. Geologist, vol. 19, 1897,

In his second paper he suggests that the name Dog Creek l changed to Stony Hills. The writer agrees that the name Do Creek is, perhaps, not the best that could be used, but in view of th fact that the dolomites which make up the Stony Hills in easter Blaine county belong to the Blaine formation and do not belong t the Dog Creek, there seems to be no good reason for using the nam Stony Hills to designate this member.

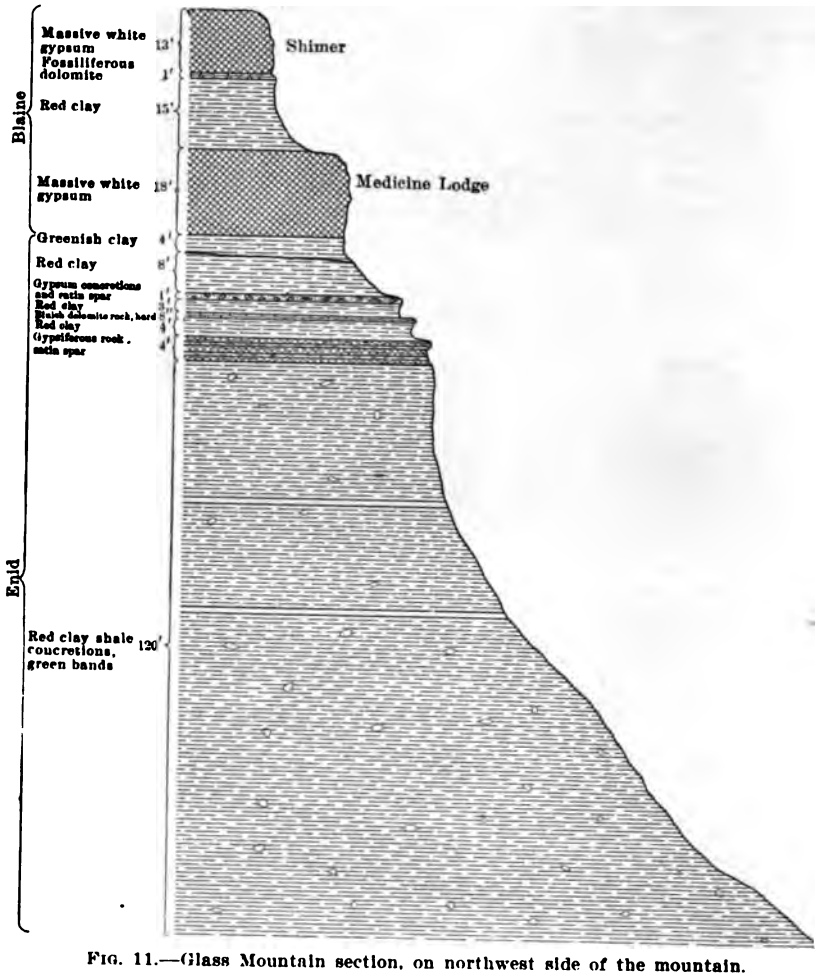


FIG. 11.—Glass Mountain section, on northwest side of the mountain.

Studies made during the last three years have demonstrated th in many parts of Oklahoma the thickness of the Dog Creek is mu greater than that given by Professor Cragin. Near Quinlan, eastern Woodward County, the aneroid readings indicate 225 fe as the thickness of these beds, measured from the top of the unde lying gypsums of the Blaine formation to the sandstones of the ne

higher formation of this member, the Whitehorse, and in a number of localities 150 and 175 feet were recorded. Exposures are common along the top of the Gypsum Hills from Canadian County to the Kansas line and beyond.

Whitehorse sandstone member.—The Whitehorse sandstone was also described (under the name Red Bluff sandstone) by Professor Cragin in his first paper, as follows:[a]

This formation consists of some 175 or 200 feet of light-red sandstones and shales. * * * Viewed as a whole it is very irregularly stratified, being in

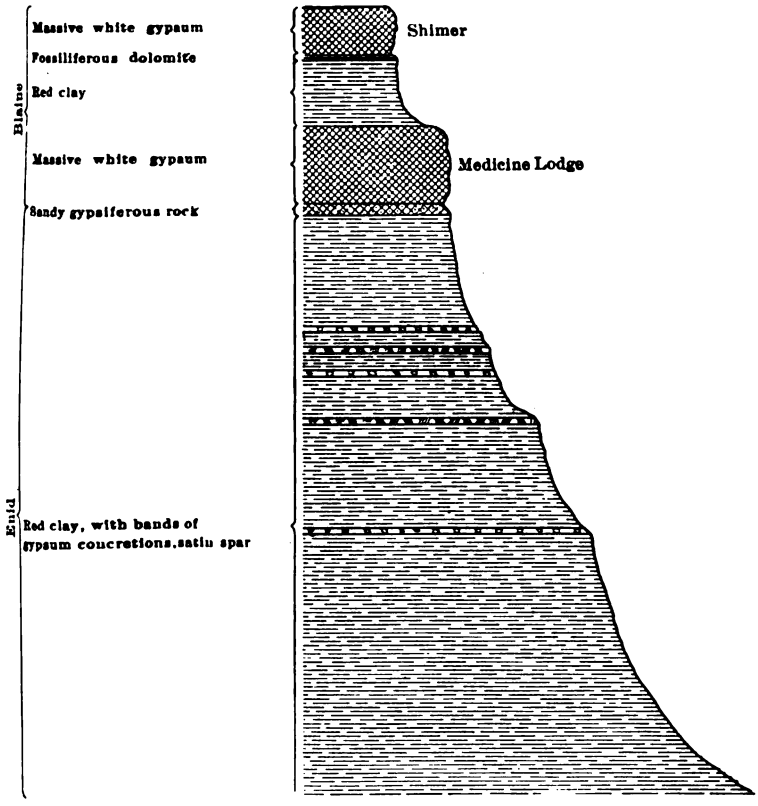


FIG. 12.—Granton section; gypsum-capped butte 1 mile east of Granton, Okla.

some cases considerably inclined, in others curved, and this oblique and irregular bedding, being on a much larger scale than that of the ordinary cross beddings, at first glance gives the impression of dips, anticlines, synclines, etc., that have been produced by lateral pressure, the dips, however, being in various directions. * * * The Red Bluff beds exhibit the most intense coloration of any of the rocks of the series. When the outcrops are wet with recent rains their vividness of color is still greater, and the contrasts of their almost vermilion redness with other colors of the landscape is most striking.

[a] Cragin, F. W., The Permian system in Kansas: Colorado Col. Studies, vol. 6, 1896, p. 40.

Spots and streaks of bluish or greenish gray sometimes occur in these ro but not to nearly so great an extent as in the lower beds. The sandstone the Red Bluffs are generally too friable for building stone, but in some stances selected portions have proved hard enough for such use and are fa durable.

In Oklahoma the Whitehorse member often weathers into conspi ous buttes and mesas. For instance, in eastern Woodward

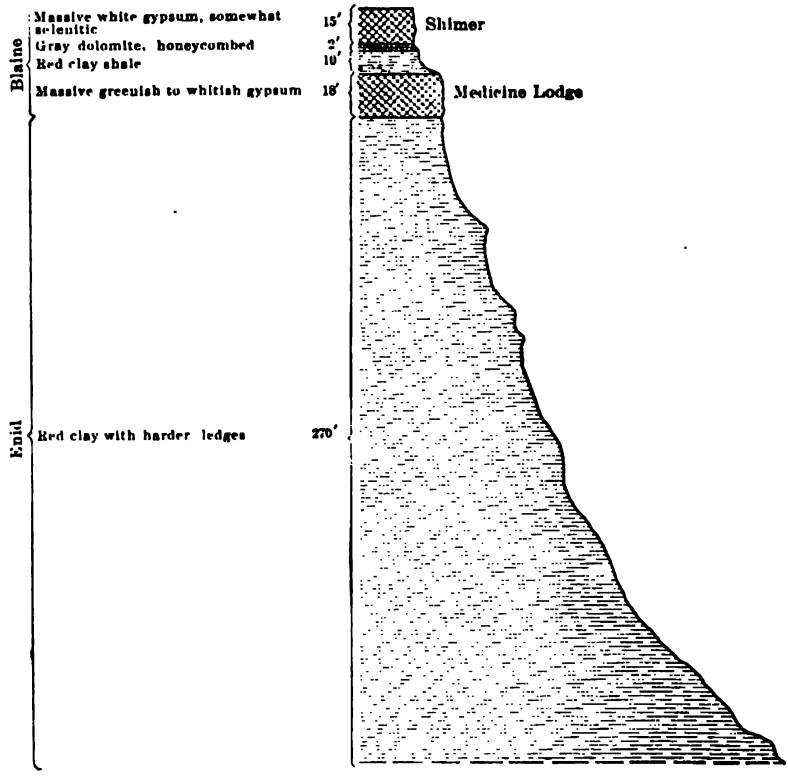


FIG. 13.--Section of hill west of the mouth of Greaver Creek.

western Woods counties a row of these buttes, which rise 100 to 200 feet above the surrounding country, extends from the vicinity of Whitehorse Springs, whence the name, southwest across the Cimarron, to the high divides beyond. To some of these buttes characteristic names have been given, as Lone Butte, Potato Hill, Watersign Hill, Wild Cat Butte, and the like. The noted Red Hill, between Watonga and Geary in southern Blaine County, is composed chiefly of the Whitehorse formation. South of South Canadian River this sand-

A. EROSION FORMS IN CADDO COUNTY BUTTES.

B. DAKOTA SANDSTONE HILLS.

stone thickens and on weathering often forms conspicuous bluffs, such as the famous Caddo County Buttes, southwest of Bridgeport, shown on Pl. X, A. The Whitehorse sandstone is exposed along the Washita from near Chickasha, Ind. T., westward, and in the vicinity of Anadarko it forms bold bluffs both north and south of the river, and extends as far west as Mountain View. Ledges which probably belong to the same general horizon outcrop north of the Wichita Mountains in the vicinity of Hobart and Harrison, and it is not impossible that further studies may demonstrate that the same beds extend under the upper gypsums across Greer County.

Day Creek dolomite.—Resting upon the upper part of the Whitehorse sandstone in Kansas and Oklahoma is a conspicuous ledge of hard, white dolomite, first described by Professor Cragin from exposures in southern Kansas, as follows:[a]

> Upon the latest of the Red Bluff rests a persistent stratum of dolomite varying in thickness from less than a foot to 5 feet or more. * * * It is a true dolomite, containing with the carbonate of lime an equal or even greater percentage of carbonate of magnesia. * * * Though not of great thickness, it is an important member of the upper Permian of southern Kansas and northern Oklahoma, owing to its persistence, which makes it a convenient horizon of reference. * * * The stone is nearly white in fresh fracture, weathering gray, and often has streaked and gnarly grain resembling that of fossil wood. * * * Its cherty hardness and fracture are not due to the presence of silica, as one is tempted to infer, but are characters belonging to it as a dolomite. It is a durable building stone.

In his second paper on the Permian rocks, in describing a typical Oklahoma locality Professor Cragin says:

> The brow of the Red Hills near Watonga, Okla., is capped with the Day Creek dolomite, which here presents itself as a compact stratum of gray, somewhat pinkish or reddish tinged cherty-hard rock, little different from the typical ledge that skirts the flanks of Mount Lookout in Clark County, Kans. The stratum here has a thickness of 3 feet.

The line of outcrop of the Day Creek in Oklahoma is not continuous: nevertheless, it is found in numerous localities, and on account of its distinctive lithological appearance it is always easily recognized. It is displayed on many of the hills of Woodward County, not only north of the Cimarron, but also between the Cimarron and the North Canadian and south of the latter stream. In Blaine County it forms the caps of a number of the prominent hills, notably the Red Hills betweeen Geary and Watonga. South of South Canadian River in Caddo County the dolomite covers the Whitehorse buttes southwest

[a] Op. cit., p. 44.

of Bridgeport and outcrops southwestward as far as the headw of Cobb Creek and on the west side of that creek past Colony. the vicinity of Mountain View, in the valley of Washita Riv ledge of dolomite appears at the same general level as that occu

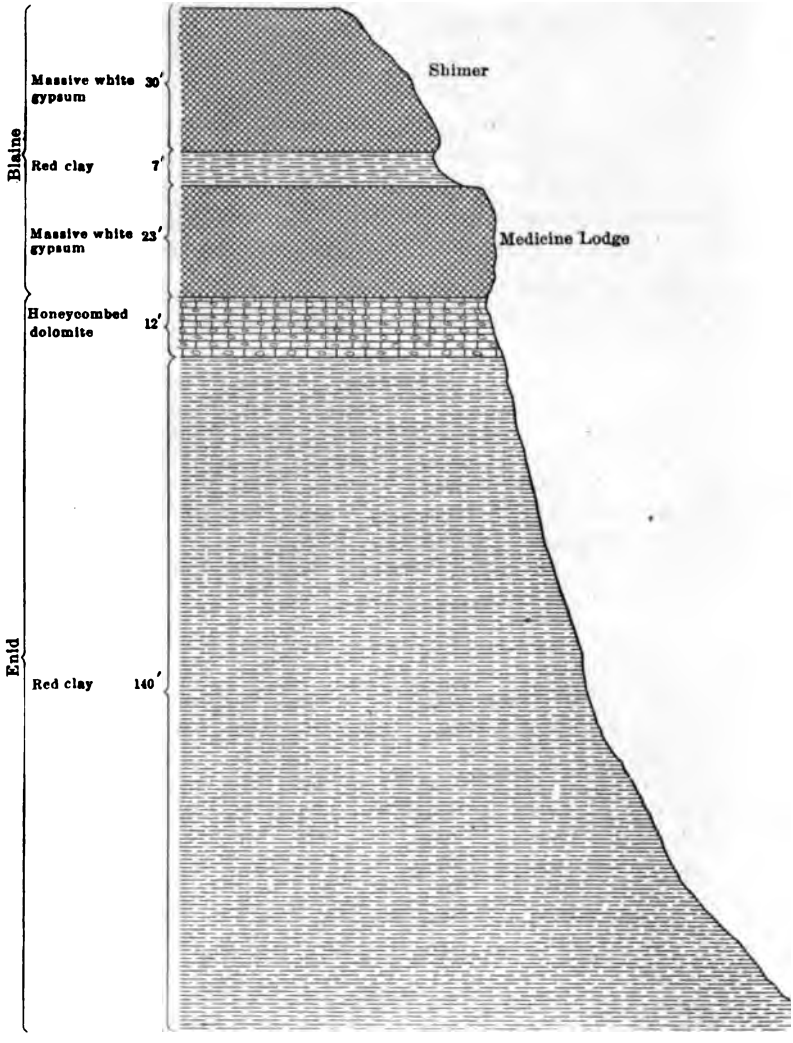


FIG. 14.—Section on Main Creek one-half mile northeast of Bat Cave.

by Day Creek, and another dolomite ledge in the hills north of] rison may provisionally be referred to this horizon.

The composition of this material in Oklahoma may be unders by reference to the following analysis:

Analysis of dolomite from the summit of the Red Hills 6 miles northwest of Geary, Okla.

	Per cent.
Calcium carbonate	42.47
Magnesium carbonate	52.86
Water	1.82
Oxides of iron and aluminum	1.35
Silica and insoluble residue	1.82
Total	99.88

GREER FORMATION.

Above the Woodward formation are red clays, shales, and sandstones, and intercalated beds of gypsum and magnesium limestone or dolomite 150 to 300 feet thick. Gypsum is the characteristic deposit of this formation, as it is of the Blaine. This formation, for which the name Greer is proposed, from the county in southwestern Oklahoma, in which it is well exhibited, is exposed over a very irregular area. For the purposes of discussion it may be grouped according to two general areas, an eastern and a western. The eastern area extends from the southern part of Woodward County southeast through Dewey, Custer, Washita, Caddo, and Comanche counties into the Chickasaw Nation. The western area extends over Washita County, touches the extreme southeastern part of Roger Mills County, and crosses Greer County to Collingsworth, Tex. The rocks of these two areas are overlain by the same formation.

The rocks of the eastern area of the Greer formation strike northwest and southeast just west of the outcrops of the Woodward formation. They are chiefly red clay shale, interstratified at several horizons with red sandstone and gypsums, which are, however, very irregularly bedded and can rarely be traced as continuous or definite ledges. Nevertheless, the thickest ledges of gypsum known in the red beds are found in this area. Thus 5 miles northwest of Weatherford a ledge 60 feet thick was measured, as shown in fig. 18; in the vicinity of Cloud Chief beds 50 feet thick are not uncommon (see fig. 19); and in a well near Seger, Washita County, a ledge 115 feet thick is reported. But these beds are not constant, thickening rapidly or disappearing without apparent regularity. Along a single bluff one may see the beds change from gypsum to sandstone within a distance of a few rods, and a quarter of a mile farther the sandstone again merges into gypsum. So variable is the stratification of all the rocks of the Greer formation in this region that no attempt is made to divide it into members. A section would usually not answer for a point half a mile away.

The most northern outcrop of this formation, so far as known, is

in the southeastern part of Woodward County, Okla., a few miles south of Richmond. It is possible that these strata represent the

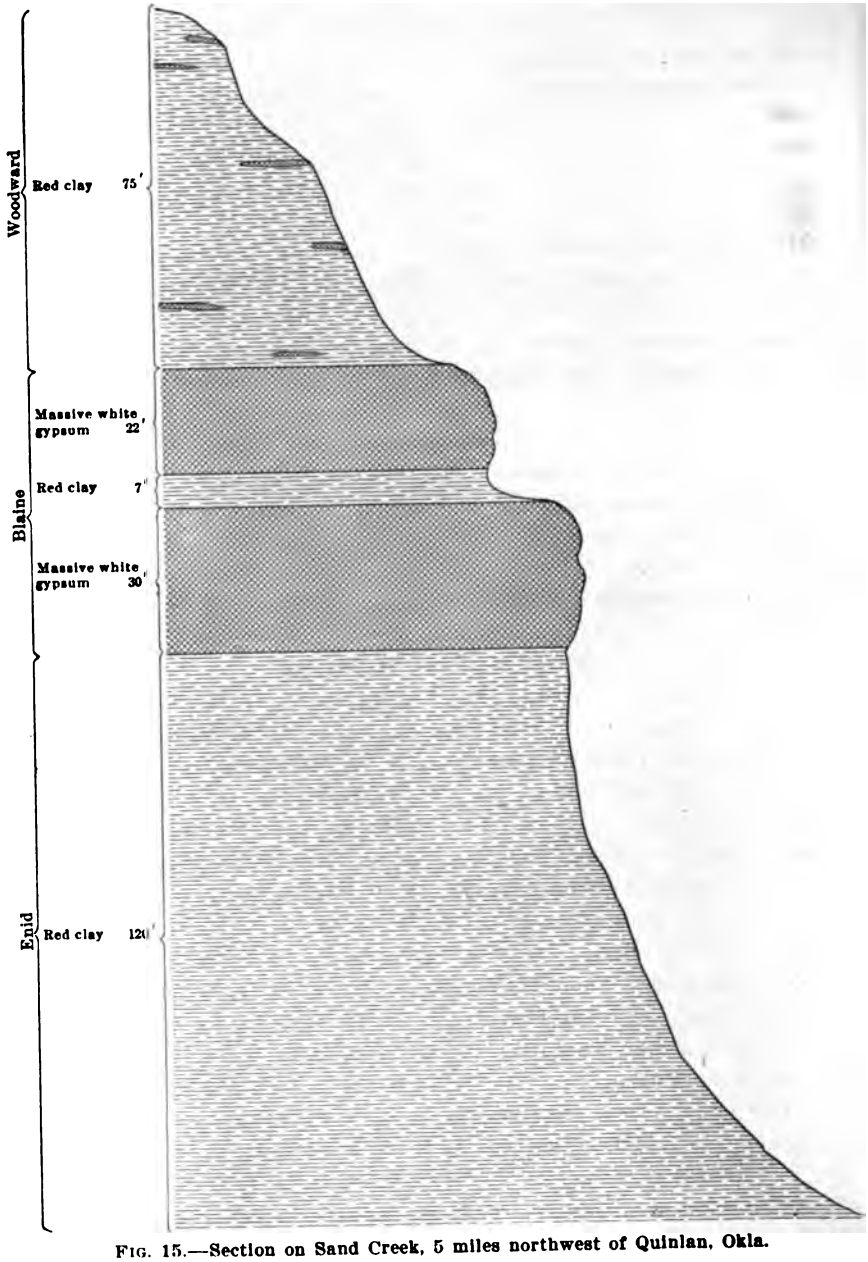


FIG. 15.—Section on Sand Creek, 5 miles northwest of Quinlan, Okla.

southern continuance of Professor Cragin's Hackberry shales and Big Basin sandstone, but further study in the field is necessary to

substantiate this point. A few miles south of Richmond, Woodward County, on the divide between the North Canadian and South Canadian, a thin bed of gypsum appears, interstratified between shales and sandstones. This ledge, which is 1 to 3 feet thick, continues south, appears as a cap to the high bluffs along the South Canadian

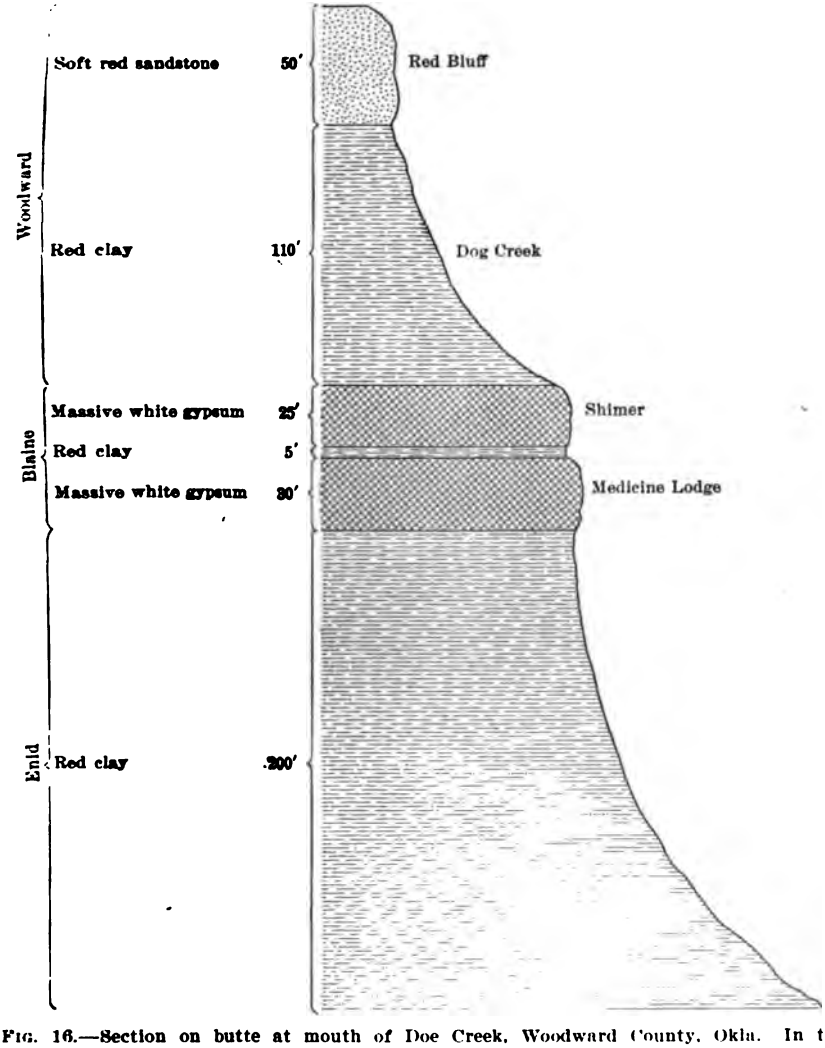


FIG. 16.—Section on butte at mouth of Doe Creek, Woodward County, Okla. In the above legend "Red Bluff" should read Whitehorse.

north and west of Taloga, and outcrops on both sides of this river as far as the vicinity of Stone, Day County. The ledge thickens to the south, and at Weatherford, Custer County, one of the beds is more than 60 feet thick. Pl. XI shows the entrance to a cave at this place, and fig. 18 a section of the hill. The various exposures,

averaging perhaps 10 feet in thickness, appear along the various branches of Barnitz Creek and the Washita River in Custer County and as far west as Roger Mills County. In eastern Washita County, in the vicinity of Seger, in the region between Cloud Chief and Weatherford, the gypsum members seem to find their extreme development, there being several heavy ledges, and one, as stated above, that has a reported thickness of 115 feet. Fig. 19 gives section of a butte on the Washita River near Cloud Chief.

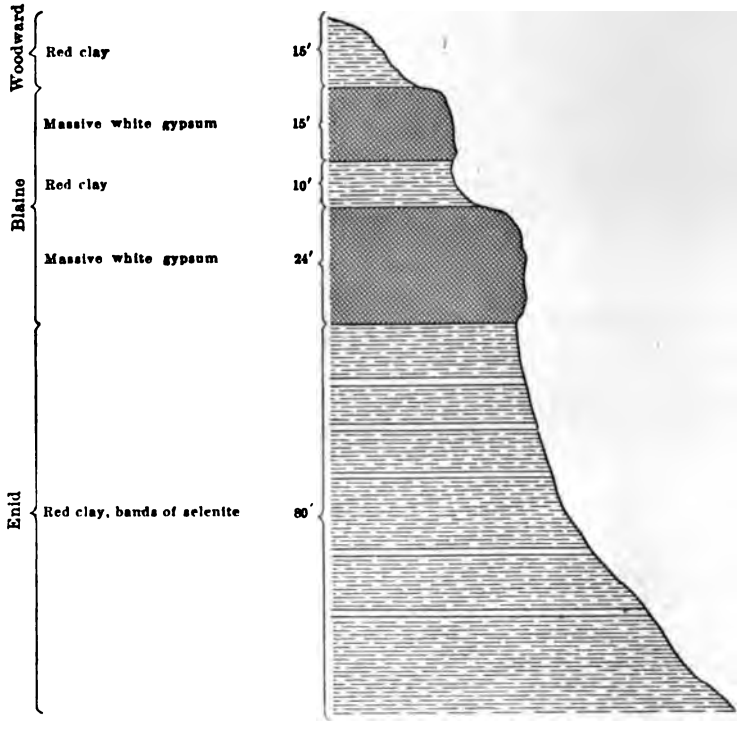


FIG. 17. Section of high bluff at southeast corner of the Salt Plain.

Following the strike to the southeast outcrops of gypsum occur on the hills north of Washita River, between that river and Cobb Creek, almost to Fort Cobb. South of that river the gypsum forms the top of conspicuous bluffs opposite Fort Cobb, and on the hills to the south and east. Exposures of gypsum continue on the divide between the waters of the Washita and those of Red River as far as the vicinity of the Keechi Hills in southwestern Caddo County, along Little Washita River (see fig. 20), and between these hills and Apache. The same beds probably extend to the region of Marlow, Ind. T.

ENTRANCE TO GYPSUM CAVE NEAR WEATHERFORD, OKLA.

The character of the gypsum in the eastern part of the outcrop of the Greer formation may be better understood by the following analyses of material taken from this region, No. 1 being from the cave 5 miles northwest of Weatherford, No. 2 from ledge 4 miles west

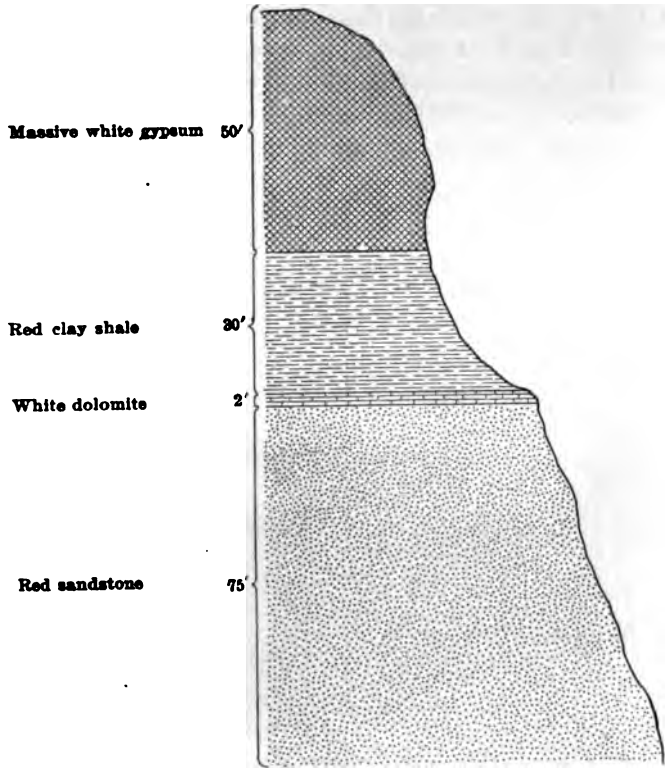


FIG. 18.—Section of bluff 5 miles northwest of Weatherford, Okla.

of Weatherford, No. 3 from 5 miles west of Weatherford (near ledge of sandstone), and No. 4 from 5 miles southwest of Cement, Okla.:

Analyses of gypsum from near Weatherford and Cement, Okla.

	1. Per cent.	2. Per cent.	3. Per cent.	4. Per cent.
Calcium sulphate	75.57	77.38	27.25	74.45
Calcium carbonate	1.11	------	46.73	4.25
Magnesium sulphate	----	.83	------	-----
Magnesium carbonate	.40	------	1.42	.84
Water	20.22	20.78	17.36	18.61
Oxides of iron and aluminum	.45	.67	8.30	.61
Silica and insoluble residue	1.66	.41	1.22	1.02
Total	99.41	100.07	102.28	99.78

In the western area of the Greer formation the rocks differ in several particulars from those in the eastern area just described. Instead of being unevenly stratified the rocks are deposited in regular layers. Sandstones are practically absent, or at least inconspicuous, and the sequence consists of layers of gypsum and magnesian limestone or dolomite interstratified among gypsiferous clays.

The rocks of this area appear to connect with those of the eastern area in southwestern Washita County, although throughout the region between Cloud Chief and the southwestern part of the county across the valleys of the various branches of Elk Creek, the gypsums ordi-

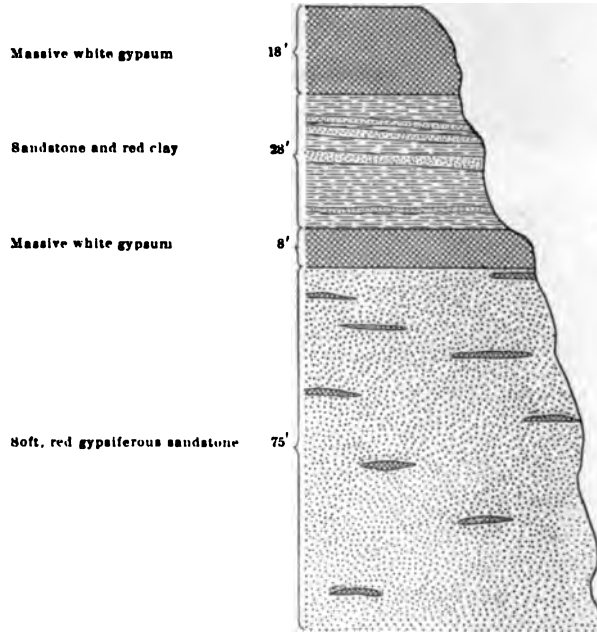


FIG. 19.—Section of butte 5 miles southwest of Cloud Chief, Okla.

narily do not appear. However, at several points along the line of strike, ledges 10 feet or more in thickness may be seen in canyons or along stream beds. Just before reaching the North Fork of Red River, and just north of the corner of Roger Mills, Washita, and Kiowa counties, regular ledges appear, and along the north side of the North Fork for 10 miles or more they form an escarpment 125 to 175 feet high, as shown in Pl. III, *B*, and fig. 21. This is, perhaps, the finest exposure in Oklahoma, the gypsum members, here appearing in four separate ledges, having a thickness of 75 feet. The river cuts through the formation west of these bluffs, and the gypsums again appear at Haystack Butte in Greer County about 20 miles

northwest of Granite. The rocks of the Greer form conspicuous bluffs on both sides of Haystack Creek and on Elm Fork of Red River and its tributaries as far as Collingsworth County, Tex. The gypsums which occur in such abundance in southern Greer County in the vicinity of Duke and Eldorado also belong to the Greer formation.

The rocks of the western area of the Greer consist of red clay shales, heavy gypsum members, and a ledge of dolomite or magnesian limestone. At the base of the formation is an unknown thickness of red gypsiferous and saliferous shales and sandstones. These shales contain occasional local ledges of gypsum a foot or two thick,

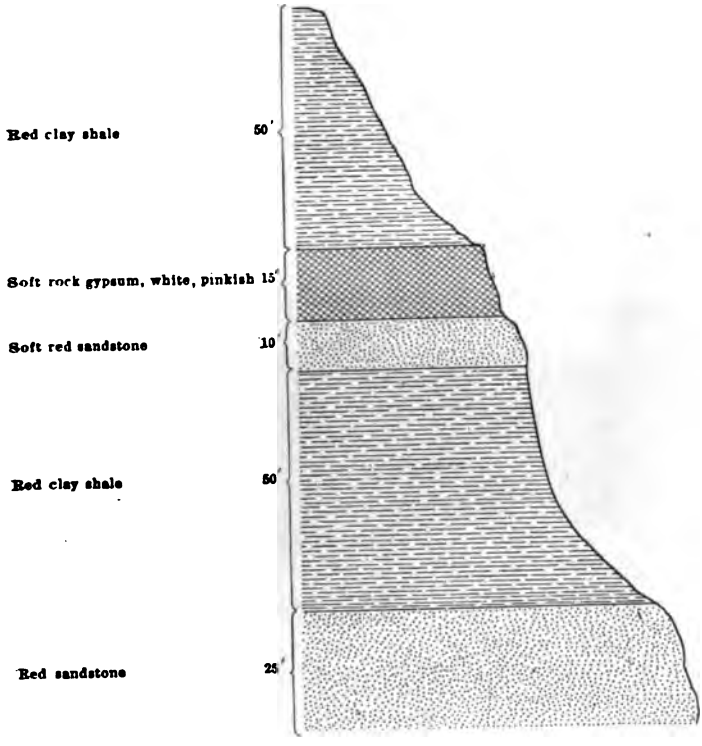


FIG. 20.—Little Washita River section, taken west of Frisco Railroad crossing.

and beds of white and greenish shales are not uncommon. In the region of the heavy gypsum formations there are several salt plains fed by springs that issue from below the gypsums, or in one instance, from shales between the gypsums. These shales between the gypsum beds do not differ materially from those at the base of the formation, nor from those between the gypsum ledges of the Blaine formation. Immediately beneath the heavy gypsum beds there is often a foot or two of bluish or greenish clay or shales. Figs. 22, 23, and 24 show characteristic sections taken in this region.

There are five prominent ledges of the Greer formation outcropping in this region, the three upper ones being thickest and most conspicuous. In general, neither of the two lower members is more than 4 feet thick, and because of their position near the foot of the bluff they are frequently inconspicuous. The various members are described below.

Chaney gypsum member.—This gypsum is well exposed along the south side of Elm Fork from Mangum northwest to the Texas line.

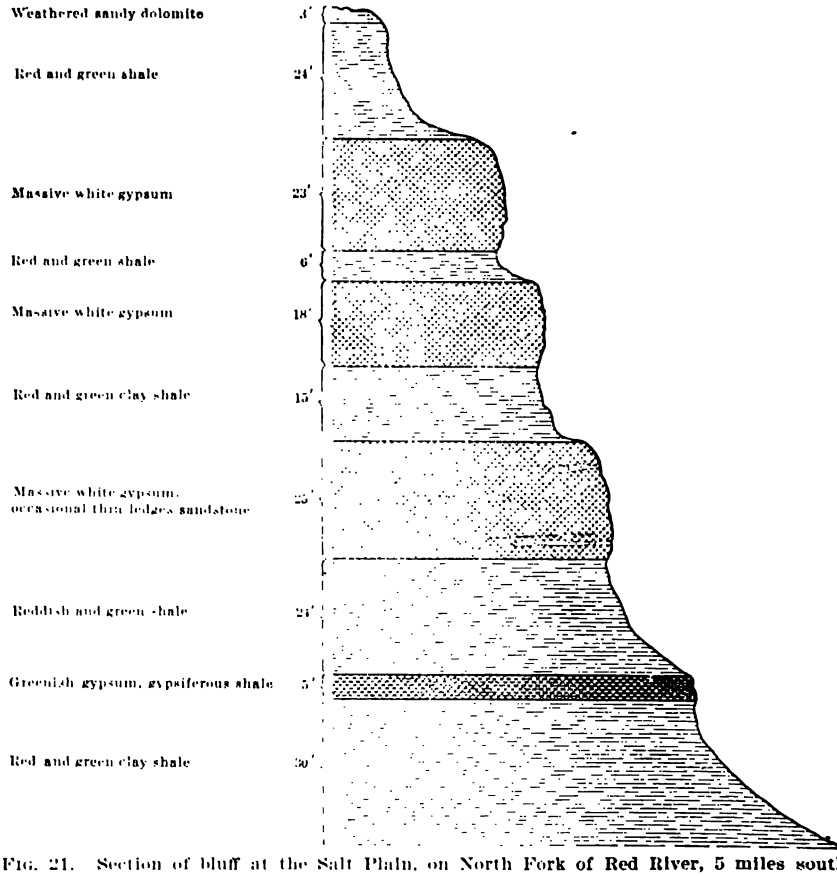
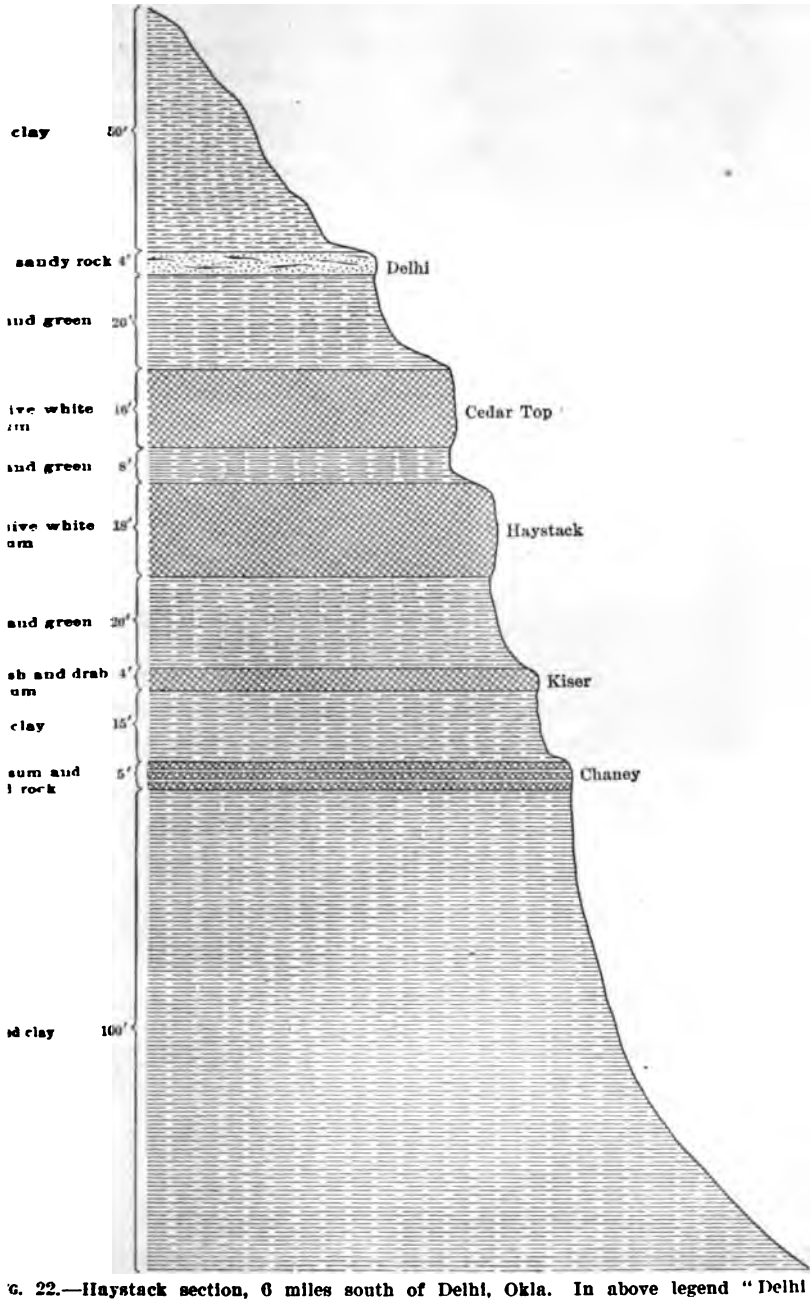


FIG. 21. Section of bluff at the Salt Plain, on North Fork of Red River, 5 miles south of Carter, Okla.

It is also seen on Haystack Creek, but on North Fork, in Roger Mills County, it loses its characteristic structure and becomes simply a gypsiferous band in the red clay. On Elm Fork at the mouth of Hackberry Creek and also at the Kiser and Chaney salt plains near the Texas line, it is a hard massive stratum 3 to 5 feet thick, usually white, but sometimes gray or bluish. It is often distinctly stratified or apparently cross-bedded, or it may be that the lines of stratification are wanting. The formation derives its name from the Chaney Salt Plain on Elm Fork of Red River, 4 miles east of the Texas line.

'iser gypsum member.—This member is exposed throughout the tern area of the Greer formation. It is rarely white and in this



G. 22.—Haystack section, 6 miles south of Delhi, Okla. In above legend "Delhi" should read Mangum.

gard differs from all other ledges of the Greer. It varies from a cidedly bluish or greenish tint to drab or gray. On the North

Fork it is composed of greenish gypsum and gypsiferous shales, becoming hard locally, and on Haystack Creek of bluish and drab gypsum, grading into gypsiferous rock and clay. On Elm Fork, at both the Kiser and Chaney salt plains, it is composed of soft, bluish to greenish, selenitic gypsum, and at the mouth of Hackberry, 10 miles down Elm Fork, it is a bluish stratified gypsum. These occurrences

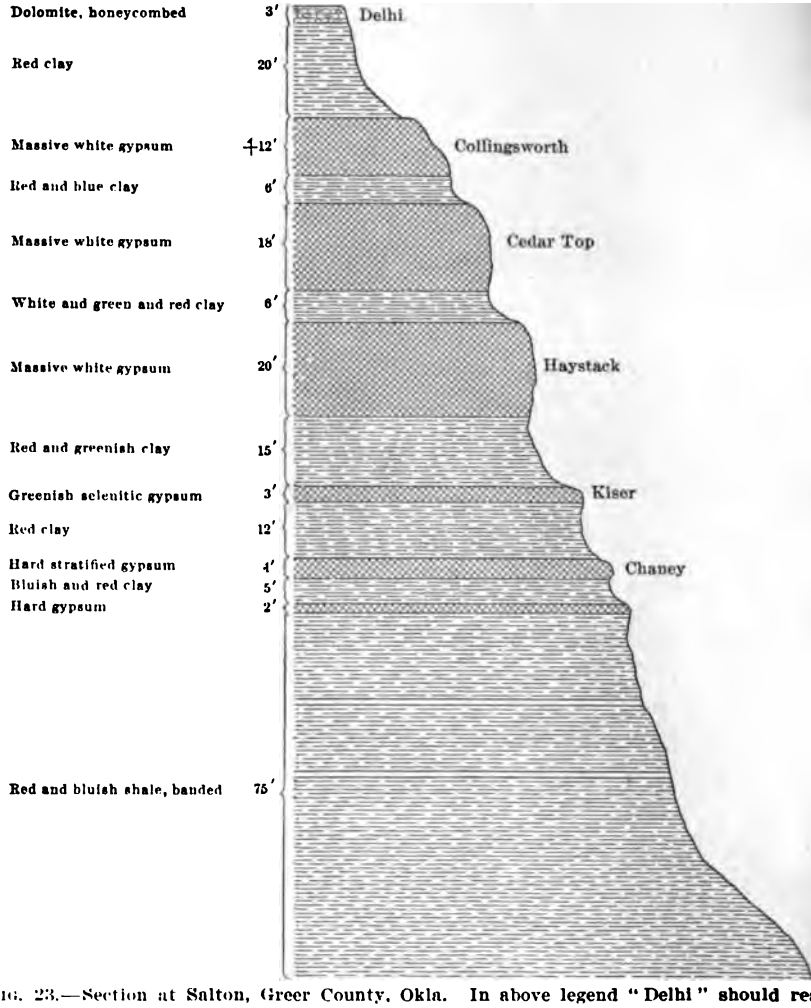


FIG. 23.—Section at Salton, Greer County, Okla. In above legend "Delhi" should read Mangum.

show that while the general character is fairly constant, the stratum varies considerably in local sections. The softness of the rock renders it particularly susceptible to weathering, and it is frequently inconspicuous. Its thickness varies from 1 to 3 feet. The name is from the Kiser Salt Plain on Elm Fork, Greer County, where the ledge is well exposed.

Haystack gypsum member.—The upper part of the Greer formation consists of three layers of massive gypsum and one of dolomite, interstratified between beds of red clay shale. The lowermost of the three thicker layers, the third gypsum member from the bottom of the formation, consists of the typically massive gypsum, almost pure white or occasionally grayish in places, with a few thin bands of gypsiferous sandstone. This ledge is often cut by joints which separate the rocks into rectangular blocks. These blocks frequently weather out and roll down the slope and in places render it conspicuously white for miles. The Haystack varies locally from 18 to 25

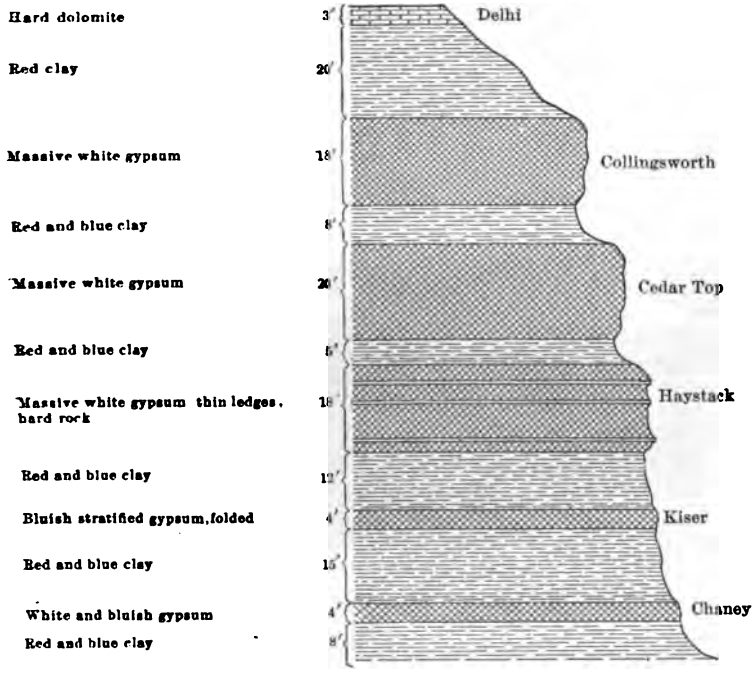


Fig. 24.—Section at mouth of Hackberry Creek, Greer County, Okla. In above legend "Delhi" should read Mangum.

feet in thickness, and so far as known is the thickest gypsum member in the western area of Greer. It is exposed along all the bluffs on North Fork and Elm Fork and is particularly conspicuous on Haystack Creek and in the vicinity of Haystack Butte, whence the name.

Cedartop gypsum member.—The Cedartop is a massive white gypsum, very similar in appearance to the Haystack. It has a constant thickness of 18 to 20 feet throughout the region of outcrop. It is very conspicuous on North Fork, Haystack, and Elm Fork, and forms the caps of a number of buttes and bluffs throughout the region. It is called "Cedartop," from a prominent butte on the North Fork of Red River, in the extreme southeastern corner of Roger Mills County.

This rock forms the upper ledge of this butte, and may be seen from a great distance up and down the river and even from Headquarters Mountain at Granite, 15 miles away. It is shown in Pl. III, *B*.

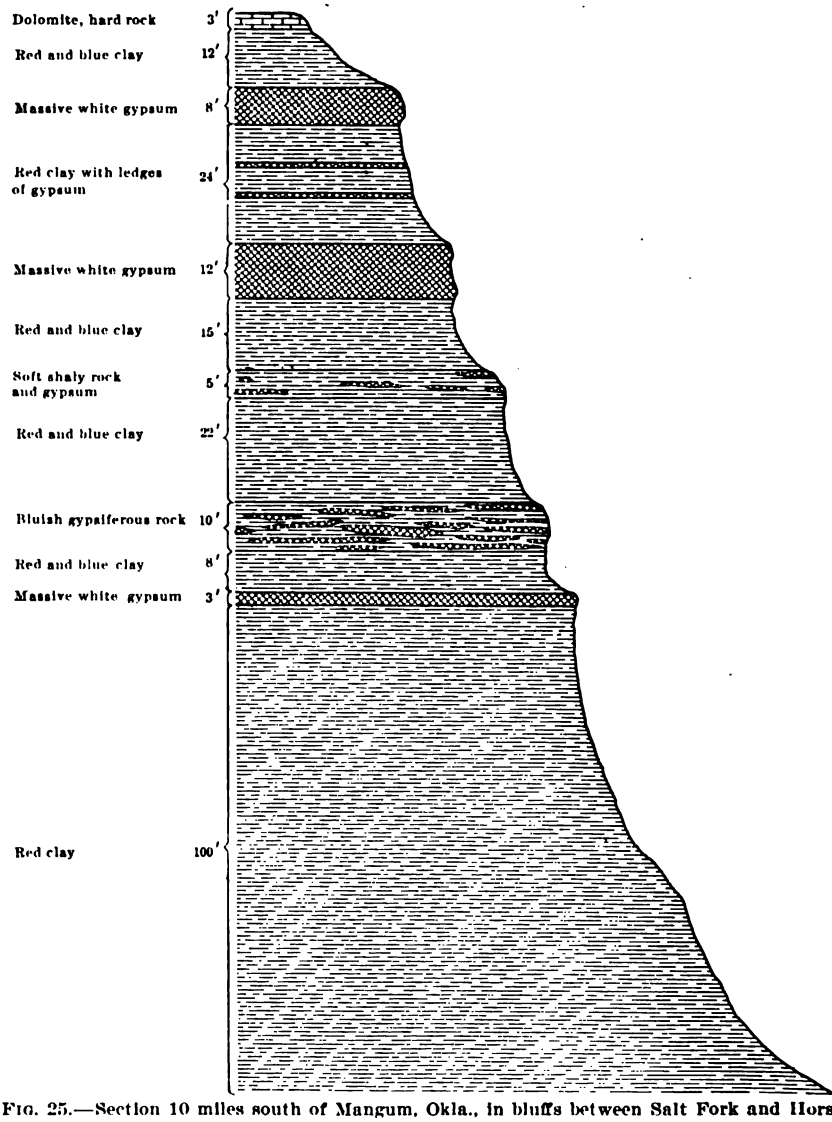


FIG. 25.—Section 10 miles south of Mangum, Okla., in bluffs between Salt Fork and Horse Branch.

Collingsworth gypsum member.—This is the upper gypsum ledge of the Greer formation, and it does not differ materially in lithological appearance from the Haystack or Cedartop. Like them, it is massive and white throughout, and like them, also, it is cut by a series of master joints into rectangular blocks. Where exposed, the

thickness varies from 18 to 20 feet, being approximately that of the Cedartop and not so great as the Haystack. As it is the upper gypsum member it has often been eroded, and for that reason does not always appear in a section. Near the heads of the various creeks, however, it is the prominent ledge, and it is also exposed on a number of the conspicuous bluffs, as along North Fork. It is named from Collingsworth County, Tex., just west of Greer County, Okla., where the gypsum is well exposed.

Mangum dolomite member.—Above the Collingsworth and separated from it by about 20 feet of red clay shale is a very persistent 3-foot bed of more or less dolomitic limestone. In places it is true dolomite; while at others it contains only a small per cent of magnesia and is a magnesian limestone. The character of the rock

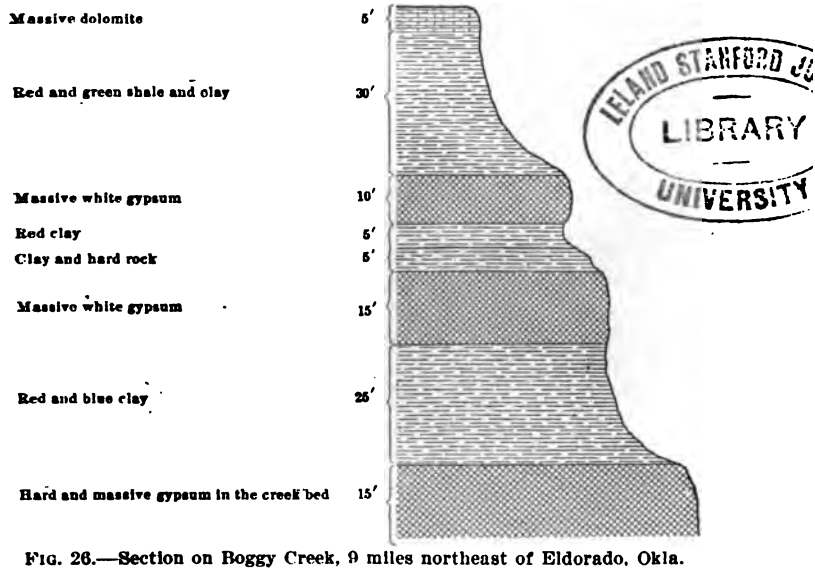


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FIG. 26.—Section on Boggy Creek, 9 miles northeast of Eldorado, Okla.

varies considerably. In places it is arenaceous and soft, in other localities cavernous or honeycombed. Often, however, it is firm and solid and forms an excellent building stone. Its color is white, drab, or sometimes yellowish. The underlying clays have often been eroded and the rock frequently covers slopes at a considerable distance below its original position. While the thickness averages 3 feet, it varies from 1 foot to 5 feet. This member is exposed on the hills north of North Fork, in Roger Mills County, and on practically all the divides of Elm Fork and Haystack, Bull, and Fish creeks in Greer County. The name of Magnum is that of the county seat of Greer County, near which the dolomite is well exposed.

Figs. 21 to 26, inclusive, showing sections taken in Roger Mills and Greer counties, indicate the stratification in that region.

QUARTERMASTER FORMATION.

Above the Greer are 300 feet or more of soft, red sandstones, and arenaceous clays and shales, to which the name Quartermaster has been applied. So far as known this is the highest formation of the red beds in Oklahoma.

In the lower part of the formation the rocks are chiefly shales, typically red, but sometimes containing greenish bands and layers. The shales become more arenaceous above, and in places form a strong, consolidated sandstone, which is rather thin bedded and prone to break into small rectangular blocks, and weather queerly into long and narrow buttresses or rounded, conical, or nipple-shaped mounds from 10 to 50 feet or more high. These mounds may be solitary, but in some areas hundreds of them occur in a single quarter-section. The sandstone is further characterized by the marked and very peculiar dip of the rocks in certain directions. The strata often dip at angles of from 20° to 40° to all points of the compass, even in a small area. These dips often produce escarpments that have the appearance of those formed by regularly bedded dipping strata. The most plausible explanation of this phenomenon is that the erratic dipping is caused by the undermining of deep-seated rocks, probably some of the various gypsum members of the Greer.

In this sandstone, particularly in its upper part, there are many springs of soft water, which usually issue as seeps at the head of deep canyons or beneath bluffs of red sandstone. While few of them have large flows, many are large enough to supply farmhouses, or, in some cases, to furnish stock water for ranches. Wells in these sandstones frequently yield good water at moderate depths. In fact, with the exception of the eastern area of the Enid, the Quartermaster is the only red-beds formation in which any large amount of good water is found.

Except where covered by younger rocks, the Quartermaster outcrops over practically all of Day and Roger Mills counties, and is also extensively developed in the western part of Dewey, Custer, and Washita counties. To the south and east it is underlain by the Greer, while to the west and north it disappears beneath the sands of the Tertiary. Streams tributary to the South Canadian, Washita, and the North Fork of Red River in the region form canyons in this rock and are fed by springs issuing from it. The name is from Quartermaster Creek, which flows from Day County through the extreme northwestern corner of Roger Mills County and empties into Washita River in Washita County. Along this creek both the lower shales and the sandstones higher up in the formation are well exposed. The peculiarities of structure and weathering are also well exemplified along this stream. In the present state of our

knowledge it is not deemed advisable to attempt to subdivide the Quartermaster formation.

RED BEDS OF UNCERTAIN RELATIONSHIP.

There are in Oklahoma two areas of red beds which are not certainly known to belong to any of the five formations heretofore described. In this report the names Lawton and Laverne will be used to designate these two areas, the term being used in a geographic sense.

Lawton area.—One of the areas referred to includes the country surrounding the Wichita Mountains on all sides, occupying practically all of Comanche and Kiowa counties, besides eastern Greer, southern Washita, and southwestern Caddo counties. The deposits of the Greer formation surround the Wichita Mountains, at a distance of from 20 to 30 miles, on all sides except on the south. (See Pl. I.) It is between these Greer outcrops and the mountains that the rocks referred to occur. They consist chiefly of red clay shales, with a few ledges of sandstone and dolomite, and in that regard correspond to the Woodward. Like the Woodward, also, these beds appear to underlie the Greer. Until the correlation of the rocks with the Texas beds south of Red River has been worked out, however, the exact relation of the red beds of this area must remain a matter of doubt.

Laverne area.—The second area in Oklahoma in which the relations of the red beds are still obscure is a narrow strip along the south side of Beaver Creek in Woodward and Beaver counties. The beds are composed chiefly of shale, with an occasional ledge of sandstone or gypsum. These beds are in strike with the outcrops of the eastern area of the Greer formation farther south in the Territory, the intervening country being covered with Tertiary deposits. (See Pl. I.) In lithologic character the rocks are also very similar to the Greer formation. Until the stratigraphy of the region is thoroughly worked out, however, the question of their correlation must remain open.[a]

Conglomerate.—At the bases of all of the Wichita Mountains, whether composed of igneous rock or limestone, are considerable deposits of conglomerate, evidently derived from the rocks of which the mountains are composed—that is, at the base of the limestone hills the conglomerate is made up of limestone bowlders, at the foot of porphyry knobs the conglomerate is made up of porphyry, while

[a] There are also exposures of red beds below Dakota and Tertiary rocks on the upper Cimarron River, in the northwestern corner of Beaver County, and extending up that stream into New Mexico. These beds may or may not be the same in age as those along the south side of Beaver Creek in the eastern part of the county. It is in these red beds near Kenton that the copper mines, which at various times have been worked with more or less success, are located.

granite or gabbro peaks produce granite or gabbro conglomerate. Near the base of the mountains this conglomerate is composed of rather large stones, sometimes as large as a peck measure. On leaving the mountains the stones become smaller and more rare, and at the same time the shales in which they are embedded become more reddish in color until at a distance of a few miles from the mountains the conglomerate has changed into typical red beds. In some places red shales approach the very base of the peaks and may occasionally be seen lying unconformably on granite, porphyry, or limestone rocks. Regarding the age of this conglomerate Mr. Joseph A. Taff wrote me under date of January 23, 1904, as follows:

> It is my interpretation that the conglomerates at the base of the Wichita Mountains are composed of near-shore deposits of the red beds and therefore are of the same age, supposedly Permian. Of course, you understand that there are considerable surfacial deposits of gravel and sand, especially in the south side of the mountains, along the valleys of West Cache Creek, which would be classed as Recent.

GYPSUM IN THE RED BEDS.

In 1902 the Oklahoma Geological Survey made an estimate of the amount of available gypsum in the Territory. The following method was employed: A ledge of gypsum a foot thick and a mile square was used as a basis, the specific gravity of the gypsum was estimated at 2.32, and the weight of a cubic foot of water at 62.5 pounds. From this it was estimated that a ledge of gypsum of the thickness given above would weigh 2,021,184 tons.

In estimating the amount care has been taken to include only available material. Throughout a large portion of the region the deposits are often covered to considerable depths by overlying shales and clays, which make up the greater part of the hill. The ledges, however, outcrop again on the other side of the hill, perhaps a mile distant. In other regions the ledges outcrop along an escarpment and disappear entirely beneath the higher hill to the west. In still other localities the ledges do not appear on the surface, but their presence is attested by numerous sink holes and by ledges encountered in shallow wells, while, on the other hand, in many places the ledges are exposed over considerable areas, and not infrequently a ledge 20 to 50 feet thick will be uncovered for half a mile or more, so that the entire thickness might be removed without being compelled to strip any material from above the ledge.

West of this region of gypsum outcrops this rock occurs beneath the surface, being encountered in deep wells at various depths, increasing to the west. In a well at Childress, Tex., about 20 miles from the southwest corner of Oklahoma, gypsum beds were found at a depth of more than 1,000 feet, and there seems to be no doubt that the ledges which outcrop in the various localities in Oklahoma extend westward

for considerable distances; passing deeper and deeper beneath the surface. It is entirely useless even to conjecture upon the extent of these deposits, for nothing but an extended system of deep borings will ever solve the problem. These deep-seated ledges have not been taken into account in making up the results. No deposits have been considered in these calculations that are more than 100 feet beneath the surface, and in general the ledges discussed are less than 50 feet deep, with the greater part exposed upon the surface.

In arriving at results the plan has been to estimate the number of square miles occupied by gypsum and the approximate combined thickness of the ledges. In both calculations care was constantly taken to make conservative estimates. The number of square miles was multiplied by the thickness in feet and this by 2,000,000. This product is considered the number of tons of gypsum in a given area.

Classified by counties the approximate amount of gypsum in Oklahoma is as follows:

	Tons.
Canadian County	50,000,000
Kingfisher County	50,000,000
Blaine County	2,500,000,000
Woods County	14,000,000,000
Woodward County	24,000,000,000
Comanche County	200,000,000
Caddo County	3,000,000,000
Washita County	20,000,000,000
Custer County	6,000,000,000
Dewey County	1,000,000,000
Day County	500,000,000
Roger Mills County	1,000,000,000
Greer County	53,000,000,000
Total	125,300,000,000

At the present there are eight mills in Oklahoma where gypsum is manufactured into plaster.

PALEONTOLOGY OF THE RED BEDS.

The scarcity of fossils in the Kansas-Oklahoma red beds has been a matter of comment ever since these rocks have been studied. In Kansas, particularly, Hay, Cragin, Prosser, Beede, Williston, and others have at various times searched carefully over the counties in which these rocks are exposed, but without avail. So far as known not a single fossil has ever been found in the Kansas red beds.

In Oklahoma, fortunately, the results have been more satisfactory. Not that fossils are abundant, for they are in fact very rare, yet enough forms have been found at various horizons to assist the geologist in the classification of the rocks. Four years ago the geologic age of the red beds was not certainly known, for at that time fossils

had been found in but one locality, and these for the purpose of correlation were far from satisfactory. Of the five localities west of the provisional base of the Permian from which fossils have been obtained in Oklahoma two only have yielded invertebrates, in two other localities vertebrates alone have been found, and from the fifth locality vertebrates, invertebrates, and plants have been secured. A brief description of these localities and the fossils obtained from each will be given.

On the farm of W. T. McCann, 5 miles southeast of Nardin, Kay County, a number of fossils were found in a ledge of sandstone which lies just at the base of the red beds. A vertebrate, identified as *Eryops megacephalus* by Dr. S. W. Williston, a small crustacean, *Estheria minuta*, and some fossil leaves comprise the collection.

Dr. E. C. Case has identified the following forms obtained near Orlando, Logan County:[a]

PISCES.

Diacranodus (Pleuracanthus) ampressus (?) Cope.
Sagenodus (?) sp.

BATRACHIA.

Diplocaulus magnicornis (?) Cope.
limbatus (?) Cope.
salamandroides Cope.
Trimerorhachis sp. Cope.
leptorhynchus sp. nov.
Cricotus sp. Cope.
Cricotillus brachydens g. et sp. nov.
Eryops megacephalus Cope.
Crossotelos annulatus g. et sp. nov.

REPTILIA.

Noasaurus sp. Cope.
Embolophorus (?) sp. Cope.
Pariotichus ordinatus Cope.
sp. Cope.
Pleuristion brachycoelous g. et sp. nov.

A number of vertebrates have recently been discovered 5 miles east of Pond Creek, Grant County. These bones have not been identified, but from superficial examination they appear very similar to the specimens from Nardin or Orlando.

In a ledge of soft, sandy dolomite which underlies the Medicine Lodge gypsum near Ferguson, Okla., a number of invertebrates have been found, among which Dr. J. W. Beede finds the following forms:

Pleurophorus subcuneatus Meek.
Schizodus (?) like S. Wheeleri.

[a] Case, E. C., On some vertebrate fossils from the Permian of Oklahoma: Second Biennial Rept. Oklahoma Geol. Surv., 1902, pp. 62, 68.

Near Whitehorse Spring, 16 miles west of Alva, a considerable number of invertebrates were obtained. Doctor Beede identified the following genera:[a] *Naticopsis*, *Pleurotomaria*, *Pleurophorus*, *Lima*, *Sedgwickia*, *Aviculopecten*, *Bakewelia*, *Conocardium*, and *Dielasma*. The last four genera are represented by new species.

AGE OF THE RED BEDS.

Regarding the age of the red beds, Doctor Williston identifies *Eryops megacephalus*, from Nardin, as a Permian amphibian, described by Cope, from Texas. Of the Orlando fossils he says:[b] "Altogether these fossils unmistakably point to the Permian." Doctor Case points out the close resemblance of these fossils to similar forms from the Permian of northern Texas, Ireland, and Bohemia.[c]

Doctor Beede, in the paper referred to, in speaking of the Whitehorse invertebrates, says:

> On the whole, these fossils show an advance over the fossils of the Permian below. Some of the species still persist, as we should expect from the fact that there is no unconformity between these various formations. On the other hand, there is a new species of *Dielasma* belonging to a group new to the American Permian. * * * Taking all this into consideration, there can be little doubt that the age of these beds is Permian.

Of these localities Orlando, Nardin, and Pond Creek are in the Enid formation; Gypsum Hills locality in the Blaine, and the Whitehorse locality in the Whitehorse sandstone, the middle member of the Woodward formation. So far as known no fossils have been found in the Greer and Quartermaster formations of Oklahoma, but there is no reason for supposing that these beds differ greatly in age from those immediately subjacent.[d]

CRETACEOUS ROCKS.

Wherever the red beds are covered by other rocks there is always a distinct line of unconformity, showing that erosion has taken place before the later rocks were deposited. As far as known there is no evidence of Triassic or Jurassic rocks in Oklahoma and the formations next higher than the red beds in the geological scale are Cretaceous rocks, which are exposed in many parts of western Oklahoma, but almost invariably in local and scattered areas. The Cretaceous rocks belong to either the Comanche or the Dakota series.

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[a] Beede, J. W., Advance Bulletin of the Second Annual Report of the Oklahoma Geological Survey, April, 1902.

[b] Letter of November 24, 1900.

[c] Op. cit., p. 62.

[d] Since the above was written fossils found in the Quartermaster sandstone in Collingworth County, Tex., have been identified by Doctor Beede, who finds that they are very similar to those from Whitehorse and of Permian age.

COMANCHE SERIES (LOWER CRETACEOUS).

In general the Comanche or Lower Cretaceous rocks in Oklahoma consist of limestone and shales. In many of the western counties these deposits are found on hillsides and are known locally as "shell rock," because they are composed largely of fossil shells belonging chiefly to some member of the oyster family.

Outcrops of the Comanche series are known to occur in the following counties: Woodward, Dewey, Custer, Day, Washita, Roger Mills, and Beaver. In every instance these rocks lie on the eroded surface of the old red beds floor, and in many instances apparently upon the flank of a former pre-Cretaceous red beds hill.

The most eastern point to which the Comanche deposits formerly reached can not be ascertained, because these deposits have been largely eroded since they were laid down. It seems probable, however, that the same deposits are but the remnant of a much larger area of the Comanche beds.

The Oklahoma Cretaceous beds form a connecting link between larger areas of Comanche series in Texas and Kansas. In the former State the Lower Cretaceous beds occur in large areas. In Kansas there are extensive outcrops of Comanche deposits near Belvidere, Kiowa County, and in Clarke, Comanche, and other counties, the thickness in places reaching 200 feet or more. Near Salina, in the central part of the State, the Mentor beds are also of Lower Cretaceous age. It is not the intention of the writer to discuss the age of these beds further than to say that it seems probable that they belong to the Washita or upper member of the Lower Cretaceous. This statement is substantiated by the fact that in the extreme northwestern part of Beaver County a series of clays containing typical Cretaceous fossils, *Gryphæa*, *Exogyra*, *Ammonites*, etc., are found lying conformably below the Dakota sandstone.

UPPER CRETACEOUS.

DAKOTA SANDSTONE.

As far as known the outcrops of the Dakota in Oklahoma occur only in the extreme western part of the Territory, along canyons cut by the Cimarron and the headwaters of Beaver Creek. Typical exposures occur near Kenton, Okla., within a few miles of the New Mexico line, and for 60 miles farther up the Cimarron, as far as the vicinity of Folsom, N. Mex. The section shown in fig. 28 was made on the Black Mesa, 2 miles north of Cimarron River, at Kenton, Okla. The Dakota in that region consists of alternating ledges of shale and sandstones, a form of structure which is characteristic of the Dakota

in central Kansas and Nebraska, where it is typically exposed. Typical Dakota hills in Oklahoma are shown in Pls. IV, *A*, *B*; X, *B*; and XVII, *A*, *B*. A few imperfectly preserved dicotyledons belonging to the genera *Populus*, *Salix*, *Ficus*, and *Platanus* were found in the sandstone rocks near Mineral, Okla. These genera are common forms in central Kansas, where dicotyledon leaves are abundant. The writer does not desire to express an opinion as to whether or not the Morrison may be found in the region of Kenton.

TERTIARY ROCKS.[a]

Lying unconformably upon the surface of the red beds and Cretaceous over a large part of western Oklahoma is an extensive deposit of Tertiary rocks, the exact age of which has never been determined with accuracy. Paleontological evidence is rare, but, following the usual classification of beds of apparently the same age in western Kansas and Nebraska, there seems no valid reason for not considering them Miocene or Pliocene. In Nebraska Darton distinguishes the Arikaree and Ogallala formations, the former being Miocene and the latter doubtfully Pliocene in age.[b] In Kansas the geologists have not differentiated the strata, and in the light of our present knowledge it seems impossible to do so in Oklahoma, and for this reason this formation will be referred to as Miocene or simply as Tertiary.

With the exceptions of the alluvium and sand hills the Tertiary is the uppermost formation in Oklahoma. The red beds underlie it, except that between the red beds and the Tertiary occur sometimes Comanche Cretaceous members, but in nearly every instance the latter are but inconspicuous beds sandwiched in between the other formations.

In general the later Tertiary occupies the uplands of the western half of Oklahoma, almost always occurring on the high divides be-

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[a] For discussions of Tertiary deposits for various parts of the Great Plains the reader is referred to the following publications:

Hay, Robert, Water resources of a portion of the Great Plains: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1895, pp. 535 et seq.

Gilbert, G. K., The underground waters of the Arkansas Valley in eastern Colorado: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, pp. 557 et seq.

Haworth, E., Physical properties of the Tertiary: Univ. Geol. Survey Kansas, vol. 2, 1897, pp. 247–284. Underground waters of southwestern Kansas: Water Sup. and Irr. Paper No. 6, 1897.

Johnson, Willard D., The high plains and their utilization: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, pp. 601–741. Continued in Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, pp. 631–669.

Darton, Nelson Horatio, A preliminary report of the geology and water resources of Nebraska west of the one hundred and third meridian: Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, pp. 719–785. Preliminary report on the geology and underground water resources of the central Great Plains: Prof. Paper U. S. Geol. Survey No. 32, 1905.

[b] Op. cit., pp. 732 et seq.

tween the streams. It comprises mostly all of Beaver County in Day and Woodward counties it occupies the extensive level pl between Cimarron and South Canadian rivers. The high between the North Fork of Red River and the Washita in w Roger Mills County is Tertiary also. In the central part of th ritory Tertiary deposits occupy the greater part of the uplands, places are known to extend nearly as far as the eastern tier of co Pls. V and XIII exhibit characteristic Tertiary topography.

Physical properties.[a]—The Tertiary consists for the most p clay, sand, and gravel. These materials are in no regular graphic succession, as shown in fig. 27. In places the entire ness of the formation is clay; again sand and gravel predon and often deposits of different character will be interbedded.

The clay is usually white or pinkish, and sometimes forms banks or cliffs along the bluffs or around the heads of canyon the harder ledges the name "mortar beds" has been applied

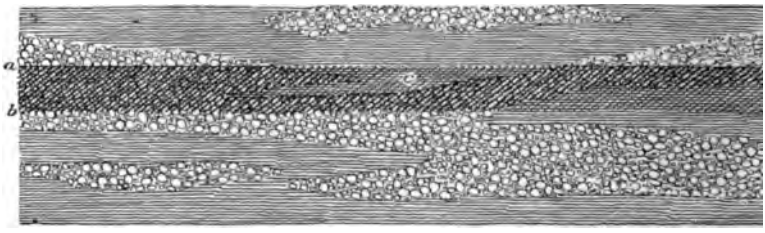


FIG. 27.—Tertiary structure, showing formation of mortar beds.

Kansas geologists. Outcrops of this formation are shown i XII, XIII, and XIV, *B*.

The sand is of various degrees of fineness, and is composed f most part of quartz, although other minerals are present. The when examined under the microscope, are usually rounded, indi the action of water.

"Tertiary pebbles" is the term usually applied by geologists smooth, rounded, waterworn pebbles scattered abundantly ov slopes and points throughout western Oklahoma and Kansas. pebbles have been washed out of the Tertiary deposits, of whic often constitute a moderately large proportion. They are freq cemented together and form a hard conglomerate rock known a tiary grit, which on exposure forms conspicuous ledges. (S XIV, A.) A good example may be seen near the head of Canyon, on the trail from Woodward to the Big Salt Plain.

The pebbles are of all sizes, from coarse sand to stones s inches in diameter. Quartz is the principal mineral, granite spar, and other minerals also being present.

[a] See article by E. Haworth, Second Ann. Rept. Kansas Univ. Geol. Survey, pp. ;

A

B

CROSS-BEDDING IN MORTAR BEDS.

A

B

MORTAR-BED TOPOGRAPHY.

A. TERTIARY PEBBLES IN PLACE.

B. MORTAR-BED STRUCTURE.

In the grits and conglomerates the cementing material usually is calcium carbonate. A drop of acid placed upon almost any of the material taken from a depth of a few feet below the surface will cause it to effervesce rapidly. In addition to the materials named above there are also in the Tertiary rocks small amounts of other substances, of which the most important are silt, black sand, and volcanic ash, but they need not be discussed in this connection.

Origin.—The Tertiary is not only the latest important deposit in point of time, but it is also the only fresh water formation in Oklahoma (except, perhaps, some Pleistocene). The Pennsylvanian, Permian, and Cretaceous are sea deposits and contain marine fossils, but the fossils of the Tertiary are chiefly bones of land animals, mastodons, rhinoceroses, camels, etc., and fresh-water shells. There has been considerable difference of opinion among geologists regarding the mode of deposition of the Tertiary, but there has never been any doubt as to the fact that the Rocky Mountains alone could have supplied the vast amount of material that has been spread out over the western part of the plains.

Extent and thickness.—It is probable that the Tertiary deposits at one time covered the entire western part of Oklahoma. The valleys of the present streams have been carved in these deposits, and in many parts of the Territory all traces of the Tertiary are gone, except scattered quartz pebbles.

The thickness of the formation varies with the locality, being greatest on the high divides. Throughout a large part of western Oklahoma its thickness averages 100 feet or more, while in a few localities distant from the streams it may reach as much as 300 feet. On the other hand, in a great many places there is but a thin blanket of the deposit over the red beds.

LAVA OF BLACK MESA.

Black Mesa extends from Colorado and New Mexico into the extreme northwest corner of Oklahoma (see fig. 28). The height of the table-land above the valley of Cimarron River is approximately 500 feet, the upper 125 of which is conposed of a black, firm, basaltic lava, which lies unconformably upon beds of typical Tertiary, both the pebbles and marl being exposed along the slope of the mesa. The Tertiary in turn lies unconformably on the Dakota sandstone. The area in Oklahoma covered by this lava is 6 square miles The age of the lava flow is not ascertained beyond the fact that it was later than the Tertiary deposits, but doubtless the flow occurred when the many volcanic peaks in northeastern New Mexico were formed.

QUATERNARY SYSTEM.

SAND HILLS.

In Oklahoma there are two general regions in which sa

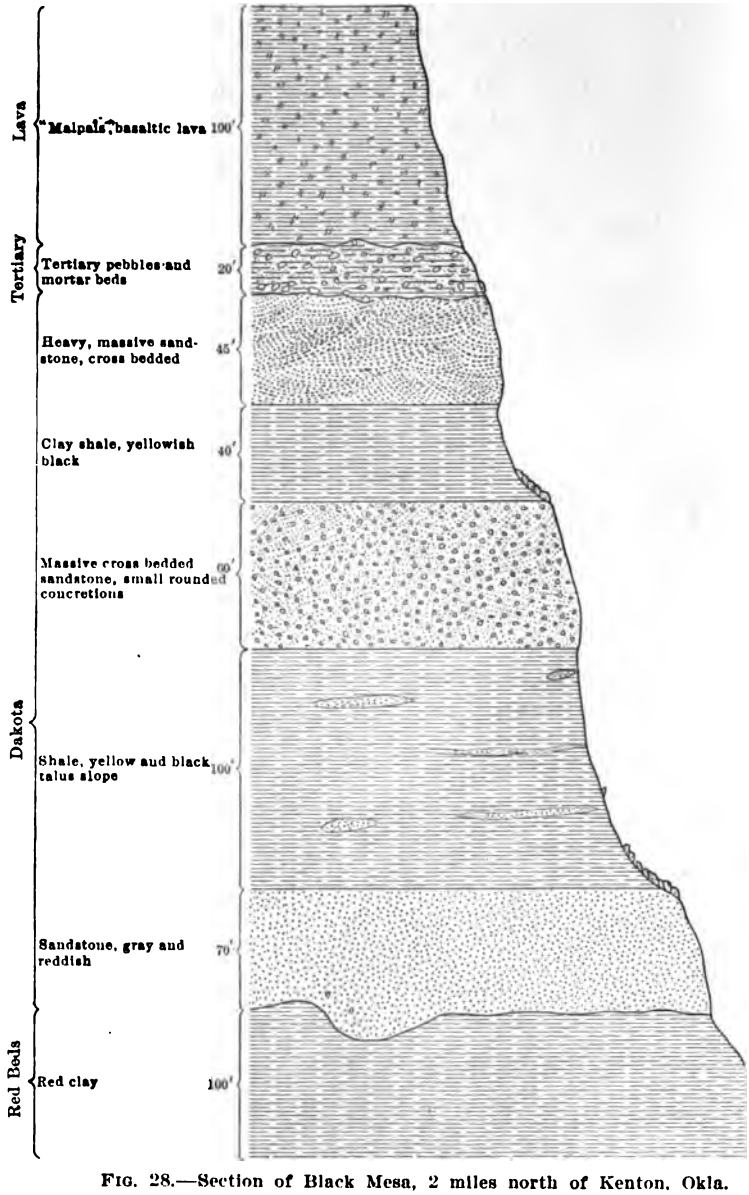


FIG. 28.—Section of Black Mesa, 2 miles north of Kenton, Okla.

occur—the first being located in the eastern tier of counties ; second in the central and western part of the Territory. T

hills of the two regions differ somewhat in origin, but all are due to the wind.

In the eastern region the sand hills are extensively developed in parts of Pottawatomie, Lincoln, and Payne counties, as well as in the eastern part of the counties immediately adjacent on the west. The greater part of this region is underlain by Pennsylvanian rocks of the Chandler district, which consists largely of ledges of soft sand rock interbedded between arenaceous shales. It is to this sand rock that we must look for the origin of the sand hills. The agents of weathering—rain, frost, temperature, wind, etc.—break down the sand rock, leaving loose unconsolidated sand grains. The modifying force is the wind. Inasmuch, however, as this is mainly a timbered country, wind action is made much less violent than in localities farther west, and so the sand hills are usually not so pronounced as in other parts of the Territory.

The sand hills of the western region are mainly the resultant of two factors—gravity and wind. Practically all of the sand is derived from the Tertiary deposits, which, as has been stated, probably once covered nearly the entire central and western part of Oklahoma. Along the streams, particularly along the southern slopes, this blanket of Tertiary beds has been largely removed by erosion; but on the divides, and on the north slopes of the streams as well, it has remained in many places. As the Tertiary deposits consist largely of clay, sand, and pebbles, and the clay is washed away more rapidly than the coarser materials, much unconsolidated sand remains in many areas. Some of this sand finds its way to the various streams and eventually chokes their channels. During times of drought strong south winds blow this sand out of the channel onto the flood plain to the north. Some persons believe that all sand hills along the streams are composed of sand blown from the stream, but the facts observed do not justify so sweeping an assumption. In many parts of the Territory there are sand-hill regions 15 or more miles wide, extending north from the stream, and on top of some of these sand hills pebbles as large as a walnut, weighing several ounces, have been found. The writer is not yet ready to admit that the wind can carry a pebble of this size and deposit it on a sand hill.

The theory of river sand being untenable in many cases, another origin must be sought. To the writer it appears most probable that the sand which forms the greater part of these sand hills is obtained directly in place from the disintegration of Tertiary rocks and that the wind is but the modifying factor. The sand hills are mainly north of the streams, and the force of gravity is also constantly at work, producing a slow but constant creeping of the sand streamward; but, on the other hand, the prevailing winds being from the

south tend to counteract the creeping motion, and so it may be assumed that the material composing the hills remains practically stationary.

Another interesting feature is the zonal arrangement of the sand hills. Every stream in the Territory, except Washita River, which is unlike all other streams of the Plains, has a row of sand hills along its north bank. Salt Fork, Cimarron, North Canadian, South Canadian, and Red rivers are all bordered with sand hills on the north side, while the south bank of these streams is usually a canyon-cut slope composed of the red clays and shales of the red beds. This subject will be discussed on pages 121, 122.

ALLUVIUM.

The flood plain, or "bottom land," of the rivers of Oklahoma is made up largely of alluvium, or, as it is often known, valley wash, derived largely from the uplands. For the most part this alluvium is composed of material derived from the disintegration of two kinds of rocks, red beds clays, and Tertiary sands and clays. In places the bottom lands have the bright vermilion hue of a red beds slope, or, again, the flood plain is made up almost entirely of white sand; but in the majority of cases the alluvium is a dark-colored chocolate loam and forms an extremely fertile soil. The extent of the alluvial deposits varies greatly along different streams. Their width is from 2 to 4 miles along such rivers as Salt Fork, Cimarron, North Canadian, South Canadian, Washita, and Red, and perhaps less than a mile along the secondary streams. The depth of the material as shown in wells varies from 2 to 30 feet.

WATER SUPPLY.

GENERAL CONDITIONS.

The water of Oklahoma varies from the purest of spring water from granite rocks or sand hills to water so thoroughly impregnated with mineral salts as to be totally unfit for domestic use. The quantity of the water is in most localities ample for all ordinary purposes, there being few sections in the Territory in which a supply may not be obtained in wells of moderate depth.

In order to study intelligently the problem of water supply in a region with so many and varied kinds of water as Oklahoma it becomes necessary to subdivide the Territory into districts, each of which furnishes water of a certain more or less uniform quality. In Oklahoma it has been found that no better general system of classification may be adopted than the one already given under the heading

"Topography," for the topographic features and character of water both depend primarily on the rocks. The topographic divisions are as follows: Wichita Mountain region, Flint-Sandstone Hills region, Low Plains region, Gypsum Hills region, High Plains region, and Dakota Sandstone region. The general outline of these various regions is given on pages 13–18, and illustrated on fig. 1 (p. 14).

Another factor which should be mentioned before taking up the various regions in detail is the kinds of rocks in which water occurs. Leaving out of account the Wichita Mountain region and the Osage nation, practically all the water in Oklahoma comes from either red beds or Tertiary deposits. In the Tertiary areas the water is almost uniformly sweet, pure, and wholesome; in the red beds, on the other hand, it is often unfit for use. The red beds are practically everywhere present at the surface, except in the western part of the Territory, where they are covered by Tertiary deposits. It will be remembered that Tertiary rocks cover nearly all of Beaver County, as well as large areas in other western counties, and occur as rows of sand hills covering the red beds along the north side of practically all the large streams nearly to the eastern part of the Territory. The water in these Tertiary sand hills is good; it follows that well-defined zones or belts of good water extend far east into the general area of red beds.

The water in the alluvial deposits along the streams is usually both abundant and of good quality. As the alluvium is composed largely of sand, clay, and loam derived from red beds and Tertiary rocks, and the amount of sand usually is sufficient to make it porous, the entire flood plain of nearly all the streams is saturated with water. Even in those areas of the red beds where good water can not be obtained from the red clays of the uplands, it is not unusual to find an abundant supply of pure water along the river bottoms, and not infrequently a small creek or even a prairie sand draw will contain a deposit of alluvium from which a considerable supply of water may be obtained. Medford, Enid, and Weatherford may be cited as examples of cities that obtain water under such conditions.

WICHITA MOUNTAIN REGION.

In the Wichita Mountains numerous springs issue from granite and porphyry rocks and furnish an abundant supply of water of good quality. Such creeks as Medicine Bluff, Blue Beaver, West Cache, Oak, Otter, and Rainy Mountain are fed at least in part by springs from igneous rocks.

In the limestone hills north of the main range springs issue from the Arbuckle limestone, and Blue, Chanler, East Cache, Rainy Mountain, and other creeks are fed in part by them. Few wells have been-

put down as far as either igneous or limestone rocks, but in m mining shafts water is encountered in such quantities as to inter seriously with the progress of the work, indicating the presenc considerable quantities of ground water.

In the red beds country surrounding the mountains, wate usually found, but in many places neither the quantity nor the qua is satisfactory.

FLINT-SANDSTONE HILLS REGION.

This region includes the Osage and Kaw reservations nortl Arkansas River, all the counties along the eastern boundary of Territory and the eastern part of Kay, Noble, Logan, Oklahoma. Cleveland counties. In other words, it comprises practically the territory east of the main line of the Atchison, Topeka and Sa Fe Railway. It is 150 miles long, north and south, with an ave width of 50 miles, and has an area of approximately 7,500 sq miles.

This region corresponds closely to the outcrop of the Penn vanian series as represented in eastern Oklahoma. In the wes part of the Osage Nation is the southern end of the Flint Hills, rocks of which consist chiefly of limestones and shales, while far east in the same reservations sandstones and shales predomin South of Arkansas River limestones are rare, sandstones and sh predominating. In this part of the region, particularly in part Lincoln and Pottawatomie counties, there are considerable area sand hills, the material of which is disintegrated sand derived f the rocks in place.

In general, this district is the best-watered part of the Territ There are several reasons for this condition: First, the rainfal from 35 to 40 inches, being greater than in the regions farther w second, the rocks consist largely of porous sandstone which is excellent water carrier; third, there is a smaller amount of min salts in the rocks of this region than in those farther west. Spr are not uncommon. In the Osage Nation, as well as in the cour south of Arkansas River, a number of springs issue from above shale beds, beneath either limestone or sandstone ledges. Wells l been put down on practically every quarter section and the gre part of them furnish good water at moderate depths.

LOW PLAINS REGION.

This region has been outlined on page 16. It extends practic from the main line of the Atchison, Topeka and Santa Railway west to the Gypsum Hills. Geologically it includes Enid division of the red beds, the rocks consisting chiefly of

clays and shales, with a few thin interbedded beds of red sandstone. North of each of the rivers which cross this region—Salt Fork, Cimarron, and North and South Canadian—is a strip of sandhills country from 2 to 15 or more miles wide.

Water from the red beds usually contains mineral salts, which in many places render it unsatisfactory for use. In Oklahoma water that is unpleasant to the taste is often called "gyp water." As the popular phrase has it, "Gyp water tastes sleek and greasy and leaves an aftertaste in the mouth." Much of the water, however, does not contain any great percentage of calcium sulphate. The most common salts are sodium chloride, sodium sulphate, calcium carbonate, magnesium sulphate, sodium carbonate, magnesium carbonate, calcium chloride, and sodium borate, in the order named. Sometimes nearly all these salts are found in the water of a single well, while in other instances but one or two may appear.

In this part of Oklahoma springs are rather rare in the red beds, and the greater part of the water for domestic use is obtained from wells. Often a farmer is obliged to sink half a dozen wells in order to find one in which the water is both sufficient in quantity and suitable in quality for general use. In certain parts of the region, notably part of Woods County, the water is often so salty as to be unfit for drinking.

Among the sandhills north of the rivers the conditions are different. Here water is both abundant and pure. Springs which issue along bluffs and wells obtain a good supply of excellent water at moderate depths.

GYPSUM HILLS REGION.

The Gypsum Hills region includes parts of Woods, Blaine, Caddo, and Comanche counties, and all counties west of these except Beaver and parts of Woodward and Roger Mills. The rocks consist of the Woodward formation, the Greer gypsum, and the Quartermaster formation. It will be remembered that the Whitehorse, the middle member of the Woodward formation, and the Quartermaster are both composed of sandstone. With these exceptions the remainder of the rocks here consist of beds of gypsum interstratified between red shales. It is the gypsum that gives the mineral character to the water. In both the Blaine and Greer gypsum hills the water of many springs is so strongly impregnated with calcium sulphate as to be undrinkable. Salt springs are not uncommon, six of the seven known salt plains in Oklahoma being at the base of the Gypsum Hills.

In wells in the Gypsum Hills water is usually reached at a moderate depth, ranging all the way from 10 to 150 feet. It usually resembl

the water from the springs in the same region and contains relatively large amounts of gypsum.

Water from the Whitehorse sandstone is usually pure and wholesome. Springs are not uncommon in this member and wells usually obtain a good supply at reasonable depths.

In the Quartermaster formation where the water is usually good the rocks consist largely of fine-grained red shaly sandstone. A very peculiar class of springs, best described by the term "seep springs," is found here, and that character is due to the nature of the rock. Usually these seep springs issue from the head of small canyons carved in the red sandstone, and bold springs are rarely found in this region. Seeps, however, are common and one not infrequently comes upon a basin which has been hollowed out in the soft sandstone and is kept full by this kind of flow. Wells in the Quartermaster usually obtain a sufficient supply of water at moderate depths. Among the sand hills areas north of the various streams springs and wells are common.

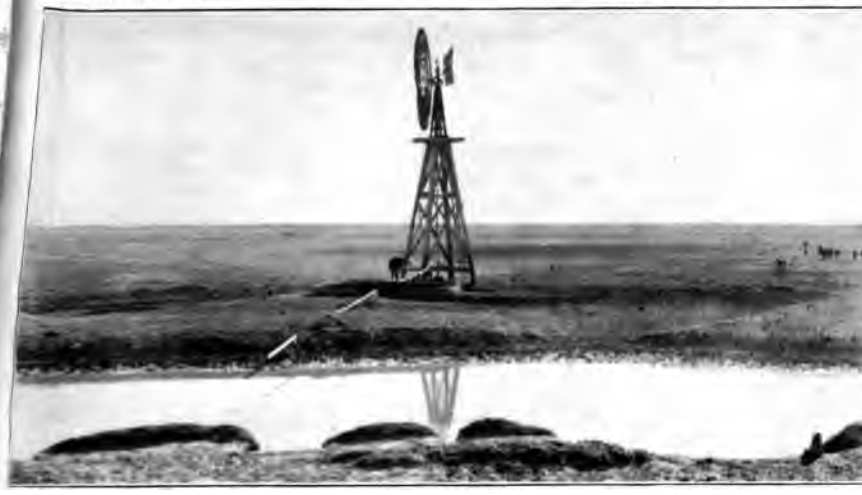
HIGH PLAINS REGION.

The Tertiary plains of Beaver, Woodward, Day, and Rogers Mills counties only are included here, although in fact the sand hills north of the various streams in the Territory belong to this division both by reason of the quality of the water and the character of the rock. In the High Plains good water is obtained almost uniformly. The Tertiary rock consists chiefly of sand, clay, and gravel, and as the sand and gravel beds almost invariably contain water, wells sunk to these beds usually secure an abundant supply. In the counties mentioned above the wells are usually deep, often as much as 300 feet or more, and windmills are used almost exclusively to bring water to the surface, but the supply is certain. In Pl. XV are shown typical High Plains windmills.

In many places where a stream has cut through the Tertiary into the subjacent red beds exposing an unconformity, a spring issues, the water of which is sweet and pure like the well water on the high plains. Some of the best water in Oklahoma comes from the Tertiary springs. Many a ranch and farmhouse and even some towns, as for instance Cleo and Grand, have been located with reference to some Tertiary spring.

DAKOTA SANDSTONE REGION.

In Kansas and Nebraska the Dakota sandstone is famous for its springs, but in the Dakota sandstone of western Beaver County springs are scarce, and so far as noticed by the writer the conditions in other parts of Oklahoma and New Mexico where these rocks are



HIGH PLAINS WINDMILLS.

exposed are similar to those in Beaver County. However, springs i the Dakota beds are not unknown and the water that is found is (good quality. Few wells have been put down in that region an consequently data for wells in the Dakota in Oklahoma are n available.

STREAMS.

None of the important rivers of Oklahoma rise in the Territor Two out of the seven—the Arkansas and South Canadian—rise i the Rocky Mountains, and the others have their headwaters on tl High Plains of Texas, New Mexico, Colorado, or Kansas, and flo across Oklahoma in a general southeast course. The Salt Fork an Cimarron empty into the Arkansas in northeastern Oklahoma; tl North and South Canadian unite before joining the Arkansas in tl eastern part of Indian Territory, and the Washita joins the Re River at the southern line of the Indian Territory. The map (P XVI) shows the drainage areas of the rivers which flow acro Oklahoma.

ARKANSAS RIVER.

Arkansas River flows southeast across the northeast corner (Oklahoma, separating the Kaw and Osage nations from the remaind of the Territory. For almost its entire course in Oklahoma it winc through a rather deep and narrow valley among the Flint Hill where it is characterized by sweeping curves and bends. In man places it flows at the foot of steep limestone bluffs, while the who region is cut into a series of hills and hollows by a number of sma creeks tributary to it.. It is estimated that during the past few yea the supply of water in the Arkansas has decreased, owing to tl fact that so much is taken out for irrigation purposes near the hea of the river. In central Kansas there seems little doubt that tl visible supply is less than in former years. Much of the water i this stream in Oklahoma comes from tributaries, such as Little Arka sas, Ninnescah, Walnut, and Grouse, that empty below Hutchinso Kans. In Kansas, where the river flows in a broad valley in tl prairie, it has a considerable underflow, but in crossing the Flint Hil this underflow is forced to the surface, and for that reason the chann rarely runs dry. Analyses Nos. 111, 112, 113, and 114 are fro waters of the Arkansas or the smaller tributaries.

SALT FORK.

Salt Fork of the Arkansas rises in southern Comanche Count Kans., west of the line of Gypsum Hills, enters Oklahoma in nort western Woods County, and flows through southern Grant and Ka

counties before joining Arkansas River. Its total length is appr mately 150 miles, 115 miles of this distance being in Oklahoma.

Salt Fork receives a number of tributaries, most of which are by springs from the Tertiary. The greater part of these enter f the north, and two of them—Medicine and Chikaskia rivers—c as much water as does the Salt Fork above the mouth of the M cine. Besides the two large tributaries just mentioned the follov creeks enter from the north: Mule, Sand, Crooked, Roundpond, tonwood, and Bois d'Arc, and from the south Coldwater, Clay, Sand creeks. These creeks are for the most part typical pr streams, with shallow valleys, low banks, and sand-filled chan and for a part of the year at least they are dry.

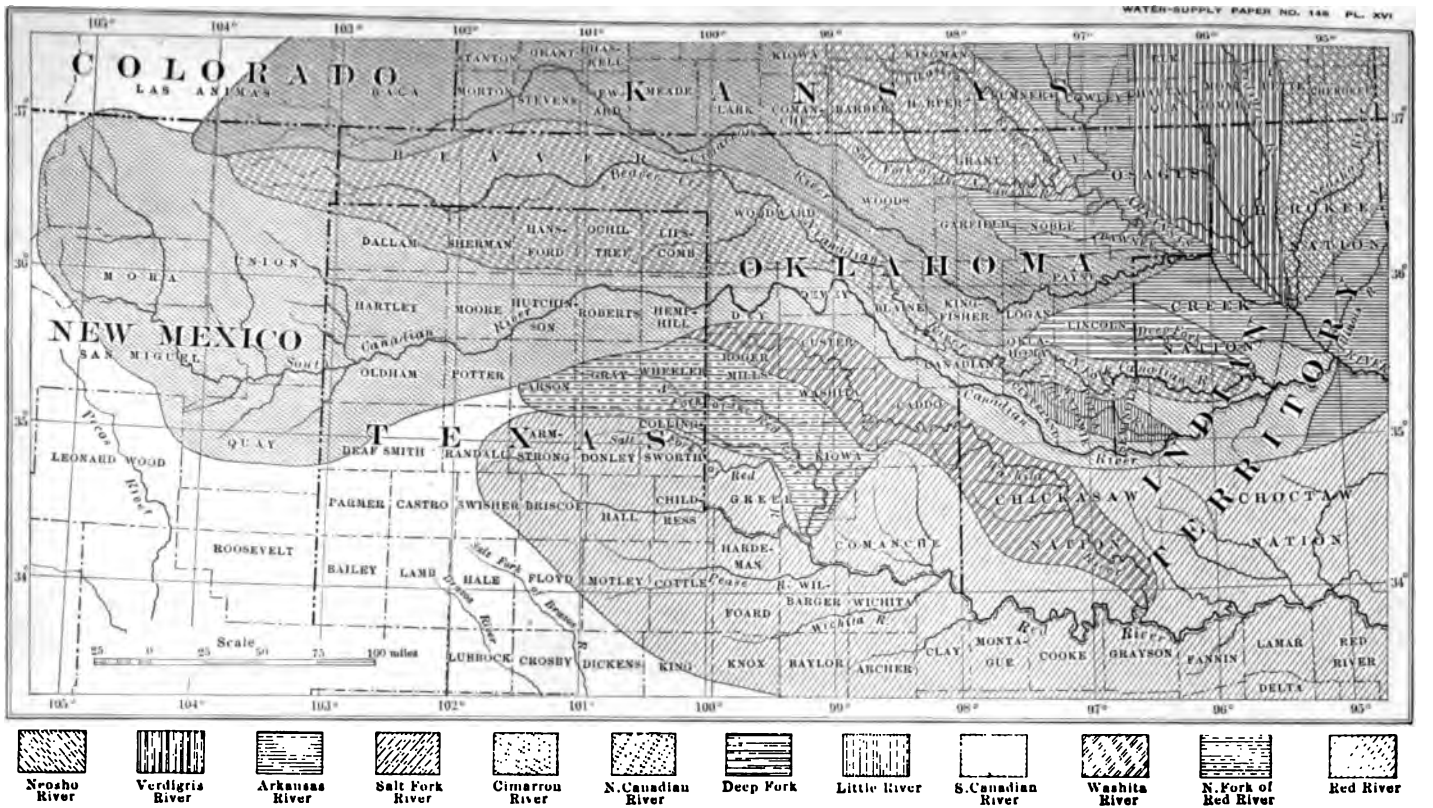
In eastern Woods County the Salt Fork flows across the nortl end of the Great Salt Plain, which has an area of approximatel square miles. It is 10 miles long and 6 miles wide, irregularly in shape, level as a floor, and, except after a rain, as white as a s field. The water of the river mingles with the saline water of plain and takes on a distinctly salty taste; so much so that at cer times of the year stock will not drink it.

Analysis No. 86 is of water taken above the Woods County Plain; Nos. 87 and 88 from below the plain, and Nos. 89 anc from small streams tributary to the Salt Fork.

CIMARRON RIVER.

The Cimarron rises among the volcanic peaks of northeastern Mexico and carries a small volume of water into Oklahoma. New Mexico and for 30 miles into Oklahoma the river flows i canyon cut through Dakota sandstone rocks into the subjacent beds. From the sandstone issue springs which supply a numbe intermittent creeks, Travessier, Carriso, Carrisoso, Tequesquite, others which flow for at least part of the year. The channel of Cimarron in this part of its course is not more than 20 feet wide is confined often by mud banks. In flowing out of the canyon the Tertiary plain, 30 miles east of the New Mexico line, the chara of the stream begins to change; the channel widens and fills sand, the banks become low, and from this point to its moutl ordinary stages of the river the water wanders about over sandy b

At irregular intervals along this river water sinks in the s and passes beneath the surface for a number of miles. For insta from the old post-office of Metcalf, Okla., to Point of Rocks, Ka a distance of 25 miles, the channel of the Cimarron is often dry, at Point of Rocks the water comes to the surface at Wagon Springs, a famous camp on the old Santa Fe trail, and the cha is usually full for a number of miles. It gradually sinks ag


COLORADO
KANSAS
OKLAHOMA
NEW MEXICO
TEXAS
INDIAN TERRITORY
LAS ANIMAS
BACA
PROWERS
KIOWA
BENT
OTERO
CROWLEY
EL PASO
PUEBLO
CUSTER
HUERFANO
LINCOLN
ELBERT
PARK
CHEYENNE
KIT CARSON
LINCOLN
EL PASO
TELLER
MONUMENT
FREMONT
CHAFFEE
GUNNISON
HINSDALE
MONTROSE
OURAY
SAN JUAN
DOLORES
SAN MIGUEL
MORA
UNION
HARDING
QUAY
TUCUMCARI
LEONARD WOOD
ROOSEVELT
CURRY
DE BACA
CHAVES
EDDY
LEA
ROOSEVELT
CURRY
PORTALES
CLOVIS
ROSWELL
ARTESIA
CARLSBAD
HOBBS
LOVINGTON
ALAMOGORDO
TUCUMCARI
SANTA FE
LAS VEGAS
RATON
TRINIDAD
PUEBLO
COLORADO SPRINGS
DENVER
GREELEY
FORT COLLINS
LONGMONT
BOULDER
CANON CITY
LEADVILLE
GUNNISON
MONTROSE
DURANGO
SILVERTON
OURAY
ALAMOSA
SALIDA
GLENWOOD SPRINGS
GRAND JUNCTION
MOAB
MONTICELLO
PRICE
VERNAL
ROOSEVELT
DUCHESNE
MANTI
NEPHI
PROVO
SALT LAKE CITY
OGDEN
LOGAN
BRIGHAM CITY
TOOELE
MILFORD
CEDAR CITY
PARAGONAH
ST. GEORGE
KANAB
PANGUITCH
TROPIC
BOULDER
ENTERPRISE
LOA
FRUITA
GRAND JUNCTION
MOAB
MONTICELLO
BLANDING
KAYENTA
TUCSON
PHOENIX
PRESCOTT
FLAGSTAFF
WINSLOW
HOLBROOK
SAN FRANCISCO
GRAND CANYON
KINGMAN
NEW YORK
BUFFALO
ROCHESTER
SYRACUSE
ALBANY
BOSTON
PHILADELPHIA
WASHINGTON
BALTIMORE
CHICAGO
ST. LOUIS
KANSAS CITY
DENVER
SAN FRANCISCO
LOS ANGELES
SAN DIEGO
SEATTLE
PORTLAND
SALEM
EUGENE
ASTORIA
SAN JOSE
SACRAMENTO
FRESNO
BAKERSFIELD
SAN BERNARDINO
RIVERSIDE
SAN DIEGO
LOS ANGELES
SAN FRANCISCO
SACRAMENTO
STOCKTON

however, before reaching Oklahoma the second time, so that above the mouth of Crooked Creek the channel is often dry. This creek, however, is perennial, and below its mouth the river carries water for many miles.

Until it flows across the Salt Plains in northern Woodward County the water of the Cimarron is pure and sweet, being derived largely from Tertiary springs, but from this point it contains so much salt that stock will scarcely drink it. Salt springs flowing from the base of the Gypsum Hills give rise to the Little Salt Plains near the Kansas line and the Great Salt Plains, shown in Pl. XX, 10 miles farther downstream.

The drainage basin of the Cimarron is more regular in outline than that of any other Oklahoma stream, averaging 40 miles or more in width across the Territory, and the stream flows approximately equidistant from either divide. The valley is from 100 to 300 feet lower than the valley of North Canadian River, which parallels the Cimarron on the south. Excluding a number of short streams in the Gypsum Hills, the principal creeks that enter the Cimarron from the north are Eaglechief, Indian, Turkey, and Skeleton, and those from the south are Salt, Kingfisher, and Cottonwood. These creeks, which will average 30 or more miles in length, enter the river at an acute angle, have a well-developed radiate drainage, and are in every way normal tributary streams, a fact rather unusual among the smaller creeks of Oklahoma.

In central Oklahoma the channel of the Cimarron is from a quarter to a half mile wide, with low sandy banks and a relatively small amount of water. For a part of each year the river runs dry, but, like all other streams of the plains, it is subject to sudden and rapid rises, at which times the river will often remain bank-full for several days. The sand partakes of the nature of quicksand, and after a rise it is unsafe to attempt to cross the river. Farther east the river enters the sandstone-bluff country and the channel is often narrowed, but the characteristic sandy condition prevails to its mouth. Water analyses Nos. 91 and 92 are from the Cimarron above the Salt Plains, Nos. 93, 94, 95, 96, 97, 98, and 99 from below the Salt Plains, and Nos. 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, and 110 are from tributaries of the Cimarron.

NORTH CANADIAN RIVER.

Beaver Creek and Wolf Creek unite at old Fort Supply, in central Woodward County, to form the North Canadian. Wolf Creek rises in the northern part of the Panhandle of Texas and flows northeast into Oklahoma, while Beaver Creek heads in northeastern New Mexico and flows east the entire length of Beaver County before reaching

Woodward. Both these creeks are fed largely by Tertiary springs and for that reason are practically perennial streams, and both are subject to rapid rises occasioned by local storms. The North Canadian has no large tributaries. With the exception of Indian and Persimmon creeks, in Woodward County, neither of which exceed 20 miles in length, there are few tributaries more than 10 miles long.

Throughout its entire course, a distance of approximately 200 miles the width of the drainage basin of the river does not average more than 15 miles, and in places the distance from the bed of the North Canadian across the divide to the waters of the Cimarron is not more than a mile. This is the case at Oklahoma City and a few miles east of Elreno.

The North Canadian has perhaps the best water of any of the larger streams in Oklahoma, owing chiefly to two causes—first, the river is fed largely by Tertiary springs; and, second, it does not flow through regions of salt springs. The waters of Salt Fork, Cimarron, and Red rivers are salty, and the South Canadian and Washita waters are derived largely from the red beds, and consequently contain both gypsum and salt. The water of the North Canadian, on the other hand, is usually soft and of a good quality. There is more timber along the banks of this stream, the flood plain is more uniform, and in general it appears more like an eastern river than any of the others just mentioned, except the Washita. Water analyses Nos. 115, 116, 117, 118, 119, 120, and 121 are of water from the North Canadian, and Nos. 122, 123, 124, 125, 126, 127, 128, and 129 from its tributaries.

SOUTH CANADIAN RIVER.

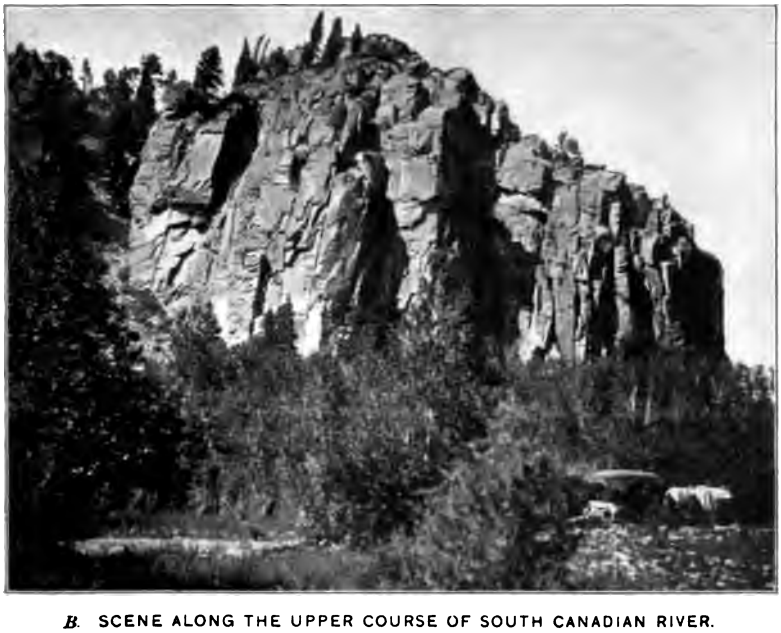
The headwaters of the South Canadian flow from the snow-covered peaks of the high ranges of the Rocky Mountains in northern New Mexico. A characteristic view along its upper course is shown in Pl. XVIII, *B*. In that territory the South Canadian drains approximately 30,000 square miles, having a drainage area of 150 by 200 miles in the northeastern part of the Territory; but in the Panhandle of Texas this basin narrows, funnel shaped, until by the time the river flows into Oklahoma, in Day County, the distance between the divides north and south of the river does not exceed 25 miles. From the Texas line to the mouth of the river, a distance of about 300 miles, the width of the drainage basin does not average more than 20 miles, while in places it is less than 10 miles. The channel of the river is sand choked, and throughout Oklahoma averages half a mile in width, the banks being low and sandy. Its channel is constantly shifting, and oxbow bends and cut-offs are common.

The South Canadian is the most uncertain and treacherous of all Oklahoma streams, and, with the exception of Arkansas River, the

A. BLUFF OF DAKOTA SANDSTONE.

B. RED BEDS DAKOTA UNCONFORMITY.

A. DAM SITE AT QUARTZ MOUNTAIN.



B. SCENE ALONG THE UPPER COURSE OF SOUTH CANADIAN RIVER.

largest. Its water supply is derived from several sources—partly from rainfall and springs in the mountains, partly from small tributary streams fed by Tertiary springs, and partly, of course, from local storms. This river, perhaps more than any other on the plains, is subject to sudden and rapid rises. The channel may be dry from bank to bank, when suddenly, without warning, a wall of foaming water several feet high, carrying all sorts of débris, will rush downward at great speed, filling the channel bank-full. For several days it will be full, when the water will gradually recede and the channel be dry again. The possible explanation of the phenomenon may be found in the fact that there is a large drainage area at the head of the river, but that it narrows rapidly downstream. A heavy storm on almost any one of the head tributaries of the river would cause it to rise, and the water flowing into the main channel, the sand of which is already saturated, would cause a sudden rise all along the river. It must be admitted that this explanation is at best far from satisfactory, and until the data from a number of gaging stations along this river have been obtained and the results studied it is improbable that we shall be able to determine all the causes that lead to this very interesting phenomenon.

Water analyses Nos. 130, 131, 132, and 133 show the character of the water from various points of South Canadian River.

WASHITA RIVER.

The Washita is an anomaly among streams of the plains. It alone has steep mud banks, comparatively little sand in the channel, and heavy timber on the bottom lands. To account for these facts it is necessary to consider briefly the nature of the region drained by the Washita. It alone of all the rivers of Oklahoma flows for practically its entire course through red beds rocks. In its upper part only does the river drain other formations, notably areas of Tertiary.

Rising in the eastern part of the Panhandle of Texas it flows across Roger Mills, Custer, Washita, and Caddo counties before entering Indian Territory. These counties are included in the Gypsum Hills region, and consequently the water of the Washita contains an appreciable percentage of mineral salts. The red clays and shales along the river bank are easily disintegrated, making the Washita the muddiest stream of Oklahoma. It enters Indian Territory and, after flowing for more than 100 miles across the red beds, passes through a gorge which it has cut through the lower Paleozoic rocks of the Arbuckle Mountains.

RED RIVER.

Red River, which forms the extreme southern boundary of Oklahoma, resembles the Cimarron or South Canadian in having a broad

and sandy channel and an intermittent flow. The name of the river is derived from the color of the water, and the red color is derived from the red beds across which the river runs.

In Oklahoma there are several northern tributaries to the Red, the chief of which are Salt Fork, North Fork, and Cache Creek. Of these North Fork and Salt Fork take their rise on the high plains among Tertiary rocks and flow southeast across the Gypsum Hills before joining the Red. Elm Creek, which is tributary to the North Fork, drains a region of salt springs. This combination of salt, gypsum, and other mineral salts makes the water rather impure. The valley of the North Fork is shown in Pl. III, *B*.

Red River is subject to sudden and rapid rises, as are the Cimarron and South Canadian. The stockmen living near the river speak of a "7-foot rise" and a "10-foot rise" as a not uncommon occurrence. This river, however, rarely runs dry, as do those farther north. Besides the Arkansas the Red is the only Oklahoma stream that empties directly into the Mississippi.

STREAM MEASUREMENTS.

There are few data regarding the discharge of Oklahoma streams, for only within the past two years have gaging stations been established in Oklahoma. During the year 1903 stations were maintained on the following streams: Salt Fork, at Alva and Tonkawa; Cimarron, at Waynoka; North Canadian, at Elreno and Woodward; Washita, at Anadarko and Chickasha, Ind. T.; North Fork of Red River, at Granite; and Otter Creek, at Mountain Park. These stations, with two exceptions, were established in 1903, and as yet the records are in an incomplete state, but they will be found in Progress Report of Stream Measurements for the year 1903.[a]

SPRINGS.

Springs can best be classified with regard to the character of the water. Following this plan the springs of Oklahoma naturally are divided into three groups—fresh-water springs, salt springs, and sulphur springs. Under the first are grouped all the springs of the Territory except those in which the water is either noticeably salty or contains an appreciable amount of sulphur. The term "fresh water," as used in this connection, does not necessarily imply the absence of mineral salts, for the water from many of the springs described is hard, containing often a large percentage of lime, gypsum, or other mineral salt. These fresh-water springs are found in all parts of Oklahoma and form a great proportion of the whole number. Salt

[a] Water-Sup. and Irr. Paper No. 99, U. S. Geol. Survey, 1904, pp. 244 et seq.

springs, on the other hand, are found in but few localities and usually under peculiar stratigraphic conditions. Sulphur springs are even more rare, occurring only in the Wichita Mountain region.

FRESH-WATER SPRINGS.

In the Wichita Mountains there are two principal kinds of springs—those from the crystalline rocks and those from the limestone. In eastern Oklahoma there are limestone springs and sandstone springs, and in the low plains there are red beds springs. Besides these there are gypsum springs, Tertiary springs, and river terrace, or alluvial springs. These will be discussed in the order given. Pl. I gives the location of such springs in Oklahoma as are at the present time known to exist.

WICHITA MOUNTAIN SPRINGS.

The Wichita Mountain region, as a whole, is well watered. A number of bold springs flow either directly from fissures in the porphyry or granite or issue along dikes, or, perhaps, at the point of contact between igneous and sedimentary rocks. Blue Beaver Springs, Talahina Springs at Cutthroat Gap, springs near Saddle Mountain, Mount Scott, and Mount Sheridan that feed Medicine Bluff Creek, and numerous springs that supply Otter, Cache, and other creeks that flow south through the mountains are of this character. In addition to these there are great numbers of relatively weak springs that issue from small fissures in granite or gabbro rocks and flow during wet weather.

The water from these springs from the crystalline rocks is notably fresh and pure, in the main the purest water of the Territory, chemical analysis revealing a very small percentage of solid residue.

LIMESTONE SPRINGS.

Under this heading will be described not only the springs issuing from the Arbuckle limestone hills in the Wichita Mountains, but also those that flow from the conglomerate that surrounds these hills, and the limestone springs in eastern Oklahoma, chiefly north of Arkansas River.

The springs flowing from the conglomerate hills north of the main range of the Wichita Mountains are probably the largest of any in the whole region. The distribution of the conglomerate is very irregular; it fills the old valleys and in some places extends beyond, covering tracts of country several miles in area to a depth of sometimes as much as 60 feet. The formation is very porous and most of the rain which falls on it is absorbed, so that the supply of

underground water during wet seasons is large, and springs often flow as much as a cubic foot of water a second. The areal extent of the formation is so limited, however, that after a few months of drought the flow from the springs either decreases materially or may even cease entirely. None of the springs are badly choked with sand, so their flow is not retarded in this way.

Most of the limestone springs of the region do not differ greatly in this respect from the conglomerate springs. They are often as strong as the former, and like them they usually go dry or run very low during dry seasons, particularly in the later summer months. The hills from which these springs get their supply of water consist of tilted ledges standing almost on edge, which naturally form a good reservoir, but these hills are so limited in size that where the water is free to escape it soon leaves the rock dry. Where banks of sand and alluvium surround the base of these hills the water is retarded in its escape, and under this condition there is a constant flow without much fluctuation. Next to the alluvial springs, which will be discussed below (p. 99), the limestone springs are more widely distributed throughout the region than any others.

The water from both conglomerate and limestone springs contains a certain amount of mineral salts, chiefly calcium carbonate, but none in quantities that render it objectionable. These springs are among the most important in the Territory.

Limestone springs in eastern Oklahoma are confined to the Osage Nation and Kay and Pawnee counties, where they occur along many of the creeks. They usually come from a ledge of limestone which immediately overlies a stratum of clay or shale, although sometimes they may be found flowing from a porous rock lying above a more impervious limestone, the largest springs of the region appearing under the latter conditions. The springs of this part of the Territory are neither large nor very numerous, the flow being limited by the impervious character of the rock as well as by the fact that the water-bearing beds are not of sufficient extent to supply a strong stream of water.

The springs which flow from the harder ledges of limestone generally are unimportant, being mere seeps, often too weak to be utilized even for watering stock. Farmers owning such seeps sometimes dig cisterns in the clay just under the point where the water appears, and by so doing manage to secure a supply of water for domestic purposes. Some of the ledges of limestone are more porous than others, and these porous or shattered ledges furnish an abundance of spring water where the overlying strata permit percolation. A condition of this kind in eastern Kay County yields several good springs, one particularly on Deer Creek, northeast of Newkirk, which issues

just over a ledge of compact limestone. This is the largest spring of this character known, and its flow averages about 0.5 second-foot.

SANDSTONE SPRINGS.

In eastern Oklahoma the whole region from Payne County southward is crossed by a number of alternating ledges of sandstone and clay, and in many places where a draw or creek cuts one of these strata a spring is found. In the northern counties the flow is usually free and uninterrupted, but farther to the south there is often a superficial covering of sand, derived from disintegration of rocks in place, through which the water flows, and eventually reaches the underflow in the sand-choked bed of some stream without appearing at the surface. In the southern counties, where this condition often occurs, there are fewest springs, but to offset this plenty of well water can be obtained at a short distance beneath the surface. In wet weather springs often appear for a few weeks in places where this blanket of sand on a hillside is not deep enough to carry off the flow of the buried spring in addition to the extra rain water which is moving down the slope, but the stream supplied by such a spring usually sinks before it goes far. The flow from most of the springs of this region is very limited. This is due to probably two principal reasons: First, the country is so cut up by small streams that the area of water tables is limited; and second, the rate of flow through sandstone is so slow that no large quantities of water can be delivered at the spring under the slight hydrostatic pressure in such small areas. Many small hills often have a half-dozen springs on their slopes. The upper ledge of sandstone usually furnishes the main flow, although a hill which contains a number of alternating strata often has seeps coming from all the sandstone formations. Few, if any, of the springs of this country will flow over 0.5 second-foot; but as a whole the region is well watered.

RED BEDS SPRINGS.

Most of the red rocks of the Low Plains region belong to the Enid formation and consist of shales and clays, with occasional ledges of sandstone. While springs occur in all the rocks, they are by no means abundant, the unbroken topography not being suitable for their development and the rock not being sufficiently permeable. The clay, however, is often a kind of joint clay and the water passes through its seams to a limited extent in veins. Where springs occur in the shale and clay of this part of the red beds they often are large. Two causes may be assigned for this. In the first place, the water beds, although with a small capacity for holding water, are of wide extent,

In the second place, the clay of the region yields readily to the action of running water, and when once a small vein is cut it soon becomes enlarged and joins with others in its vicinity, thus producing a bold spring.

The quality of the water of these springs is variable, some of them yielding soft and palatable water, while others are heavily charged with sulphur and gypsum. The conditions which bring about these different characteristics are local. Bois d'Arc Springs, in Kay County, are charged with gypsum, while not far from these are Willow Springs, the water of which is almost soft. Timberlake Springs, in Woods County, on the western border of the plains, flow soft water, while a number of springs not far east of them contain gypsum. The springs flowing from the sandstone of the region resemble those coming from the same kind of formations in the eastern part of the Territory, except that they are never choked with sand.

GYPSUM SPRINGS.

In the Gypsum Hills region, in the western part of the Territory, are numbers of springs in which the water is strongly impregnated with calcium sulphate, which are consequently known as "gypsum springs," or more popularly as "gyp springs." The greater part of the springs of this kind issue from directly beneath heavy ledges of gypsum, and in many cases are due to underground streams. The Gypsum Hills country is full of sink holes and caves, most of which contain underground streams. Such caves and sink holes as are shown in Pl. XI and fig. 9 are abundant.

Gypsum springs such as those just described are particularly common in Blaine, Woodward, Washita, and Greer counties, where the Gypsum Hills have their most conspicuous development. Some of them are strong, flowing as much as 5 second-feet.

TERTIARY SPRINGS.

Springs occur in the sand hills north of the rivers from the western line of the Territory as far east as the eastern limit of the Low Plains, as well as in the High Plains region of Beaver, Woodward, and Day counties. In the western part of the High Plains region they flow out near the rivers on both sides of the stream, but farther eastward they appear chiefly along the divides of the rivers. Before reaching the Gypsum Hills, the Sand Hills formation, from which they flow, disappears along the south sides of the rivers, but continues, usually in the form of a heavy row of wind-blown sand hills, on the north sides. These hills, as well as the springs flowing from them, extend eastward across the Low Plains country and gradually grow smaller, finally disappearing in the eastern part of the Territory.

A

B

TERTIARY SPRINGS AND CONTIGUOUS TOPOGRAPHY.

The springs in these hills as far west as the High Plains almost always issue along the lines of unconformities between the Tertiary deposit above and the red beds beneath, usually where a creek has cut through the sand into the red clay and shale below, thus exposing the water plane, as shown in fig. 29. In some places the water flows out along a bank for a distance of several hundred yards, as in the case of Cleo Springs in Woods County; in other cases it issues as a single bold stream—for instance, in Bents Canyon in northern Woodward County. In many cases these springs boil up from the sand, and are often called boiling springs. Springs of this kind are, in fact, artesian in character, and will often raise the water to a height of several feet if confined. In Pl. XIX Tertiary springs and characteristic contiguous topography are shown.

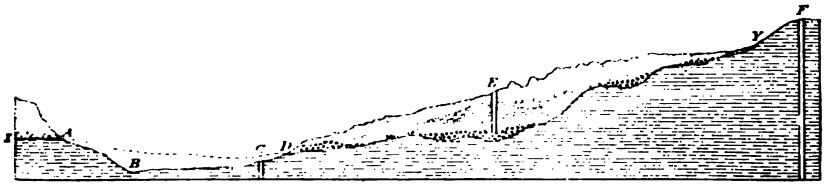


FIG. 29.—Ideal section of Tertiary springs. *A*, *D*, Tertiary springs; *C*, *F*, wells in red beds; *E*, well in Tertiary.

It can be said almost without exception that all Tertiary springs yield relatively strong flows. The material from which the water comes and through which it circulates is so coarse that the flow is less impeded than in the case of any other class of springs of the Territory, unless, indeed, it be the springs flowing from the conglomerate in the Wichita Mountains. An immense amount of water is allowed to go to waste every year by not utilizing these springs. In some instances the owners are using them for irrigation purposes, but as a general rule little attention is paid to their economic value. The city of Alva uses water from a Tertiary spring. It is carried by gravity through pipes a distance of 2 miles to a cistern and is then distributed to the different pipe lines of the city by pumps. The supply is more than adequate. None of the Tertiary springs have been known to go dry during the droughts which are common to the region in which they occur. They sometimes diminish in flow, but this is rarely ever the case. The water of the Tertiary springs is almost without exception soft and palatable.

ALLUVIAL SPRINGS.

Springs of this kind occur along the rivers in all parts of the Territory, but are most common in the Wichita Mountains and along Arkansas River. The alluvial springs of the Wichita Mountains are found along the banks of every stream of the region,

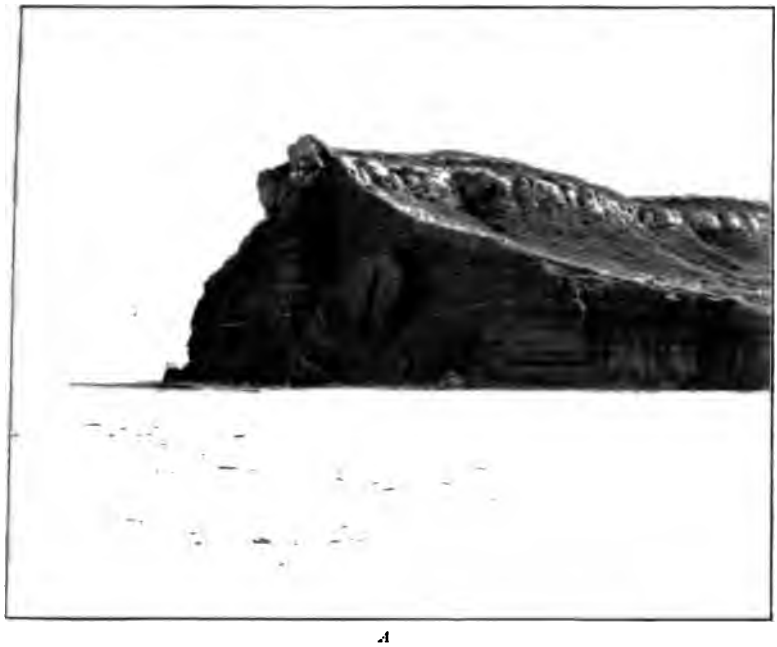
issuing just above the surface of the water or flowing out onto the low bottom lands. Nearly every piece of low land has at least one spring flowing from it. They are rarely strong. The flow usually comes from the base of the deposit and trickles out for several rods along the bank, or else it issues from a single outlet. These springs furnish a large amount of water to the creeks, and altogether they probably do more than their share toward supplying the running water of the region. On account of their number and distribution they are probably of more economic value than the other springs of the mountains, but at the same time are less conspicuous.

Along Arkansas River in Oklahoma these springs from terrace deposits usually are large, although in many cases they do not flow out in a bold stream, but hundreds of small seeps come out along a bank for several hundred yards and the aggregate is a large stream of water. In the Wichita Mountain region these springs appear near the present creek beds, but along Arkansas River they usually flow from terrace deposits which are now many feet above the river channel. These deposits are rarely over half a mile wide and seldom more than 30 feet deep. The springs flowing from them seldom go dry and are rarely ever affected by drought.

SALT SPRINGS AND PLAINS.

Wells and springs, the water of which contains an appreciable amount of common salt (sodium chloride), are found not only throughout the red beds, but also in the Pennsylvanian rocks, and in certain regions the water from the springs is of such noteworthy salinity as to warrant the popular phrase "salt spring" or "salt plain." Leaving out of account the regions in eastern Oklahoma in which the water is but slightly salty, it is proposed to describe the localities, particularly in the western part of the Territory, in which salt springs and salt plains are common.

There are two salt plains in Woodward and Greer counties and one each in Woods, Blaine, and Roger Mills counties. These plains have a wide geographical distribution and vary greatly both in size and amount of flow. While all the salt springs come from Permian red beds, they do not issue from the same geologic horizon. The Woods County plain is located a little more than halfway up the Enid formation of the red beds, the Woodward and Blaine county plains are supplied by springs that issue near the top of the Enid, not far below heavy gypsum members of the Blaine formation, and the Roger Mills and Greer county plains are found either near the base of the Greer formation, or, in some instances, springs are known to issue between gypsum ledges which are members of the Greer.



A

B

SALT PLAINS ON THE CIMARRON.

WOODS COUNTY PLAIN.

This is the largest of all the Oklahoma Salt Plains and also the only one that contains no large salt springs. It is located just south of the Salt Fork of the Arkansas in the eastern part of Woods County, about 35 miles from the nearest point of the gypsum hills, and includes an area of approximately 60 square miles, extending about 10 miles north and south and 6 miles east and west. The plain is as level as a floor, and on ordinary occasions as white as a snow field, from the incrustation of salt crystals which cover it. It is absolutely barren of vegetation, with only here and there a scattered bit of driftwood to break the monotony.

The origin of the salt on this plain is somewhat obscure. About the margin of the plain are a few weak salt springs, but they rarely furnish sufficient water to form a running stream. On digging a hole a few feet deep in any part of the plain, however, salt water begins to run in, and in ten minutes the hole will fill up to a point within 6 inches of the top. The plain is composed of loose reddish-brown sand and clay, which is apparently everywhere saturated with salt water. The surface evaporation of this water gives rise to the white salt incrustations which render the surface of the plain white, except after a rain which has dissolved the salt crystals. To the writer the only plausible explanation of the origin of the salt water is to suppose that it comes from a large number of small springs which issue from the red beds at the bottom of the plain. There is no way of estimating the amount of flow from this plain, but total volume of water is many second-feet.

WOODWARD COUNTY PLAINS.

In Woodward County there are two salt plains, both located in the valley of the Cimarron and fed by springs which issue from red shales 50 to 100 feet below the Medicine Lodge gypsum. Locally these plains are known as Big Salt Plain and Little Salt Plain, the latter being just south of the Kansas line, where the Cimarron River first breaks through the line of gypsum hills.

The Big Salt Plain is located 12 to 20 miles farther down the Cimarron, extending for 8 miles or more along the river. In width it varies from half a mile to 2 miles. On the south bank the bluffs of red shale and sandstone capped with gypsum rise directly from the edge of the plain to a height of 100 feet or more, as shown in Pl. XX. North of the plain these hills are not so steep and are at a distance of half a mile or more from the plain, but even here the sinuous white line of gypsum may be traced along the tops of the bluffs as far as the eye can reach. In other words, the plain lies in a broad canyon of

the Cimarron, inclosed on both sides by gypsum-capped red sha hills.

The plain is flat, except for a few meandering channels which i wet weather contain small streams of water, but are ordinarily dr After a rain sometimes a stream of considerable volume flows dow the channel across the plain, but during the summer months nearl all the water either evaporates or sinks into the sand. In plac where a small stream still runs down the channel the water is ofte so salty that a thin crust of crystal white salt, resembling a sheet c ice, forms on the surface of the stream. The entire plain is covere with a thin incrustation of snow-white crystals, which in most plac does not exceed an eighth of an inch in thickness, but which reflec the sunlight like a snow field.

In a large cove among the gypsum-covered red hills on the sout side of the plains proper are a number of salt springs, which boil u from the flat surface of the plain. The water is crystal clear, and sometimes requires more than ocular proof to convince one that it co tains nearly 50 per cent of salt. There are scores, perhaps hundred of these springs on an area of but a few acres, some of which flo streams as large as a man's arm; others are much weaker. In a cases the presence of a spring is marked by a conspicuous whi incrustation of salt, which forms around the spring and along th sides of the little stream that flows from it. Particles of grass weeds blown into these springs or streams soon become covered wit white salt crystals, forming strings of them which are often an inc or more in diameter and look like rock candy. In places the incrust tions around the springs are so thick that the salt may be scraped u and hauled away. Beds of rock salt are reported from this plai but have never been seen by the writer. The combined flow of th various springs which feed the plain will approximate perhaps 2 or second-feet.

BLAINE COUNTY PLAIN.

Besides the two plains of the Cimarron, just described, the Sa Creek plain, in northern Blaine County, is also fed by springs whic issue from below the gypsum ledges, and, like the others, it is locate in a canyon at the foot of the Blaine Gypsum Hills. This plain i much smaller than the Big Salt Plain just described; its widt is not more than a quarter of a mile in the widest place, and for th greater part of its course is not more than 100 yards, with a lengt of perhaps 3 miles.

The region of Salt Creek is one of the most picturesque spots i Oklahoma. The upland is covered with jack oak and the capping o Tertiary sands breaks off abruptly into precipitous cliffs and canyon

A SALT SPRING ISSUING FROM BENEATH GYPSUM LEDGE.

B. LOG AND EARTH DAM ON UPPER CIMARRON RIVER.

200 or more feet deep, the slopes of which are composed of the brick-red shales of the upper part of the Enid formation, capped by massive white gypsum ledges of the Blaine formation. (See Pls. VII, *B*, and IX.) Numerous narrow canyons with cedar-covered slopes radiate outward from the head of Salt Creek, a tributary of the Cimarron. In the head of the main Salt Creek canyon are the springs which supply the plains. A ledge of red and blue mottled cross-bedded sandstone outcrops along the heads of several branches of the main canyon, and from it issue the springs, the waters of which form a small creek. Along the bottom of the canyon salt incrustations, formed by evaporation, cover a narrow strip of 100 yards or more of the sandy level. A mile below the springs the canyon widens, the creek leaves the wall of hills and enters the flat country, the salt plain spreads out to become in one place as much as a quarter of a mile wide. A mile or so farther downstream it is joined by creeks which do not carry salt water, and it soon loses its individuality.

From the standpoint of economic importance the Salt Creek plain bids fair to exceed all others in the Territory, as it is nearer to the coal fields of the Indian Territory, as well as near to market. A number of primitive salt plants have at times been located along the edge of the plain. The methods employed in securing the salt are extremely simple. A well is dug in the sand of the plain and the water pumped by hand into vats and evaporated by boiling. Fuel, chiefly cedar and oak, was formerly obtained from the canyons near by. It is stated that three buckets of brine will make one bucket of salt. The capacity of one of these plants is approximately 2,000 pounds per day. The salt is hauled in wagons to supply local trade, and the demand is said to have exceeded the supply for a number of years.

The Oklahoma Salt Company has erected a plant with a capacity of 450 barrels per twenty-four hours at Ferguson, Okla., the nearest railroad point to the plain. The brine is obtained from open and drilled wells and is carried 2⅛ miles in a 2½-inch wrought-iron pipe. Steam will be employed to operate rakes, elevators, conveyors, etc. Pans are of cement 12 by 150 feet and 20 inches deep.

ROGER MILLS COUNTY PLAIN.

In the extreme southern part of Roger Mills County, on secs. 10, 11, 14, and 15, T. 8 N., R. 22 W., is a salt plain occupying an area of about 40 acres. This plain, which is about half a mile distant from the North Fork of Red River, is located near the base of the Greer Gypsum Hills, which in this region are well exposed. In places springs of salt water issue directly from beneath gypsum ledges, as shown in Pl. XXI, *A*, while in other instances the water boils up in the form of bold springs from the level surface of the plain. The

are in all 20 or more springs, the waters of which unite to form a stream estimated to flow at least 1 second-foot, although, in view of the fact that a great part of the water sinks into the sand, it is probable that this amount represents but a part of the actual flow. Salt has been manufactured at this plain for many years. The water is said to contain a considerable proportion of gypsum, but not so much as to render it unfit for use.

GREER COUNTY SALT PLAINS.

The two Greer County salt plains are located in small canyons which have been carved in Gypsum Hills, south of Elm Fork of Red River, about 5 miles east of the Texas line. From the names of the owners these plants are known locally as the Chaney Salt Plain and the Kiser Salt Plain. Neither covers an area of more than an acre or two. Both are fed by springs that issue from the red shales below heavy ledges of Greer gypsum. Springs boil up from the level sand floor, and the water flows out of the canyon to mingle with the water of the river. A flourishing local industry has been carried on at these plains for twenty years or more, and some years as much as 600,000 pounds of salt have been manufactured at each one. Since the timber, which formerly grew in the canyons, has been exhausted solar evaporation has been largely employed to produce salt. The average combined flow from the springs is estimated at 1 second-foot from each plain. In a number of canyons emptying into Elm Fork in this region there are salt springs, but no others have sufficient strength of flow to warrant the establishment of salt plants.

Salt has been manufactured at various times on all of the salt plains of Oklahoma except the large plain in Woods County, which, as stated above, contains no springs of any size. Until the present time, however, primitive methods only have been employed, and no considerable amount of capital has been invested. It goes without saying that salt springs of this character will ultimately develop into properties of much value. Ten or more second-feet of saturated brine will not always remain unutilized.

SULPHUR SPRINGS.

All the springs in Oklahoma which may be denominated sulphur springs are located in the vicinity of the Wichita Mountains. In all there are a score or more, the greater part of which are mere seeps, located usually among the limestone hills which lie north of the granite peaks of the Wichitas. The three which are hereafter described are probably the strongest of the lot.

GRANITE SULPHUR SPRING.

This spring is located in the northwest part of the town of Granite, Greer County, Okla., in a cove south of Headquarters Mountain, the westernmost of the high peaks of the Wichita Range. The water issues from deposits of clay and gravel close to the granite rocks at the foot of the mountain. The water is comparatively pure except for a small quantity of sulphides. The spring has quite a reputation and its water is used for medicinal purposes.

RAINY MOUNTAIN SULPHUR SPRING.

Standing out on the plain in the eastern part of Kiowa County are three limestone knobs, the extreme northwestern outliers of the range of limestone hills referred to above. From a small ravine at the base of one of these hills there issues a sulphur spring which from its location near Rainy Mountain is known as the Rainy Mountain Sulphur Spring. It is situated in sec. 33, T. 7 N., R. 15 W. Not only sulphur, but salt as well is found in the water of this spring.

APACHE SULPHUR SPRING.

This spring is about 10 miles southwest of Apache, Comanche County, Okla., in sec. 32, T. 5 N., R. 12 W., near the foot of one of the limestone hills that make up the range lying north of the Wichitas. The flow of the spring is small; the source of the water is probably in the limestone rock.

DEEP WELLS.

GENERAL CONDITIONS.

Within the past few years a number of deep wells have been put down in various parts of Oklahoma. These wells have been bored for water, gas, oil, and other products.

Because of the fact that shallow wells do not always furnish a sufficient amount of water, efforts have been made in various places to find deep-seated waters, and in many instances they have been successful. So far it has been found that if a depth of 400 feet is reached without securing the desired amount and quality of water there is little use in going farther. The reason for this is that the greater part of Oklahoma is underlaid with red shales, which usually contain a large percentage of salt, gypsum, or other mineral salts. So far as known, except along the eastern edge of the outcrops of the formation, the drill has never penetrated to the base of these red shales, and so their thickness is unknown.

In this discussion only those wells that have reached a depth of feet or more will be considered. Any classification of deep wells t might be made must be largely an arbitrary one, but perhaps classification based upon the purpose for which the well was dril will more fully meet the conditions in Oklahoma than any other, a for this reason the deep wells of the Territory will be described un the two heads " Water wells " and " Oil and gas wells."

WATER WELLS.

Fort Reno well.—In 1893 a well 1,370 feet deep was drilled at F Reno, Canadian County, for the purpose of securing a supply water for the post. The well, however, failed to secure enough g water for the purpose intended and was abandoned. A small amo of salt water was encountered at about 400 feet and fresh water 441 feet. This is the only well in the Territory in which fresh wa is found below 400 feet. The rock passed through consisted mai of red shale. The section is given in Pl. XXII, *A*.

Kingfisher well.—At Kingfisher an attempt was made to sec deep-seated water, and at a depth of 600 feet a great flow of str salt water was encountered, the water rising to within 8 feet the top.

Optima well.—At Optima, in north-central Beaver County, a w was drilled to a depth of 498 feet without obtaining water, a rat rare occurrence on the high plains. The strata passed through se to be all Tertiary deposits, and the depth indicates the thickn which these deposits attain. The log given in Pl. XXII, *B*, shows rocks passed through.

Childress, Tex., well.—The Fort Worth and Denver Railr Company had a well put down at Childress, Tex., 15 miles southw of the southwest corner of Oklahoma, in an effort to secure water engines and shops. The water found was impregnated with salt a gypsum, and therefore unfit for use. The rocks passed through w red shale, clays, thin sandstones, and gypsum and salt beds. Th formations being soft caved badly, and the well was abandoned. T log of the Childress well is given in Pl. XXII, *C*.

OIL AND GAS WELLS.

Wells in the Osage Nation.—Along the eastern line of the Os Nation, from the Creek country to Kansas, a number of wells h been sunk for the purpose of securing oil. In a number of these b oil and gas have been found, the former product running as hi as 200 barrels per day and the latter product several million cu feet per day. The wells pass through shales, limestones, and sa stones of Pennsylvanian age. Salt water is frequently encountered

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a depth of 1,400 feet. A log of one of these wells, near Bartlesville, is given in Pl. XXII, *D*.

Cleveland well.—At Cleveland, Pawnee County, a well was drilled to a depth of 520 feet through comparatively thin ledges of red and blue shales and sandstone with two limestone members. Salt water was found at 220 feet and rose to within 40 feet of the surface.

Newkirk well.—At Newkirk, Kay County, in the northern part of the Territory, several wells have been drilled for oil and gas. These wells start on top of the Flint Hills, and consequently pass through a larger amount of limestone than any other wells in Oklahoma. A small amount of oil was encountered in all the wells, but not enough to pay for the cost of drilling. Salt water was found at various depths, in one instance rising to within a few feet of the mouth of the well. The log is given in Pl. XXII, *E*.

Shawnee well.—The log of the Shawnee well, given in Pl. XXII, *F*, illustrates the conditions along the eastern edge of the red beds, where alternating strata of shales and sandstones make up the entire formation. If the well had been continued a few hundred feet deeper, there is no doubt that the drill would have passed through the red beds into the subjacent members.

Jet well.—The Saline Oil and Mining Company has put a well down 975 feet at Jet, Woods County, in the hopes of securing oil and gas from the red beds. The well passed through red and blue shales all the way, with the exception of about 8 feet of sand at 280 feet, which are reported to have yielded one to three barrels a day. Soft water was reported at 180 feet. The log is shown in Pl. XXII, *G*.

Anthony, Kans., well.—This well was drilled 12 miles north of the Oklahoma line. A study of the log (Pl. XXII, *H*) will assist in understanding the conditions in the northern part of the Territory. At this point the red beds are 551 feet thick, below which are 395 feet of blue shales and 404 feet of salt beds. Limestone, notably that of the Flint Hills, was encountered at 1,350 feet.[a]

CONCLUSIONS.

From the above facts and known conditions the following conclusions regarding the underground conditions in Oklahoma may be drawn: (1) In general, water may be obtained in fair quantities between the depths of 200 and 400 feet, but such water often contains a high percentage of soluble salts, which sometimes render the water unfit for use. (2) Water below 400 feet is almost invariably too

[a] Since the above was written a well at Spencer, 12 miles east of Oklahoma City, has been put down to a depth of 2,050 feet. The red beds were penetrated at 1,550 feet below which gray to brown shales and sandstones were encountered.

salty for any purposes except for the manufacture of salt. (3) Drilling wells to any considerable depth in the red beds is difficult, because of the unstable and treacherous character of the formations.

ARTESIAN WATER.

There is little hope for artesian water in Oklahoma. The Dakota sandstone, the great artesian water-bearing formation of the plains, outcrops only in the extreme western part of the Territory. Tertiary rocks carry large quantities of water, but, so far as known, the structural conditions are not suitable for an artesian flow. The red beds are water bearing, but in the main sparingly so, and, besides, they all dip westward or toward the higher lands.

Flows of artesian water depend upon several conditions, among which the two most important are (1) a porous stratum of rock contained between impervious strata; and (2) an exposure of this porous stratum at the surface at a higher elevation than the mouth of the well. It has been thought that in Oklahoma these conditions might be furnished by the red beds, which extend westward far up the flanks of the Rocky Mountains, but the rocks have not been found to yield flows. As to prospects in the subjacent rocks, the difficulty is that the drill has rarely penetrated the red beds in Oklahoma. In one or two instances wells which started in the red beds have reached the blue and gray clays and shales below, but in these instances the wells were located near the eastern margin of the red beds. Salt water only was found in these wells and in no instance did it reach the surface. The relations and capabilities of the formations underlying the red beds in central and western Oklahoma remain to be settled.

There are a few local instances of flowing wells in Oklahoma, but none of economic importance. At Guthrie a well in the red beds flows over the surface. Near Beaver City an artesian well is reported from the Tertiary.

In many parts of Oklahoma are wells that are semiartesian in character; that is, the water rises in the well often nearly to the top, but does not flow out. At Newkirk, in a well which was drilled 1,680 feet for gas or oil, salt water was encountered which rose practically to the surface. In the vicinity of Norman there is a water-bearing stratum at a depth of about 250 feet below the surface, and in a number of wells which have reached this stratum the water rises from 150 to 175 feet, standing within 75 to 100 feet of the surface. This fact may be readily explained by remembering that the rocks at Norman dip west 10 to 20 feet per mile, while the surface slopes to the east. The sandstone in which the water is found at a depth of 250 feet comes to the surface some miles east of Norman, and at a

level lower than the mouth of the well. Under this condition the water rises to the level of the intake area, which is 75 to 100 feet below the level of the mouth of the well.

WATER CONDITIONS, BY COUNTIES.

In the following pages will be discussed briefly the general conditions of water supply in each of the 27 counties (counting the Osage Nation as one). The order is as follows: First, a brief mention of the rocks and the principal drainage features; second, a statement of the character of the wells and springs; and third (pp. 156, 173), a list of 10 wells from the county. These well records, more than 250 in all, have been selected from about 3,000 records now on file in the office, and are believed to represent fairly well the water conditions of the various counties.

OSAGE NATION.

Rocks and drainage.—The Osage Nation, which includes all of Oklahoma lying north and east of Arkansas River, is approximately 50 miles square. Tributary to the Arkansas in the Osage Nation are Beaver, Salt, and Gray Horse creeks. The greater part of the Nation is drained by Verdigris River, through Hominy, Bird, Buck, and Sand creeks. In the eastern part of the reservation the rocks are chiefly shales and sandstones, with an occasional ledge of massive limestones, while farther west to the Arkansas River the limestone ledges are more frequent. In this reservation the Flint Hills reach their highest development in Oklahoma, although they are here not so conspicuous as in Kansas. South of the river the limestone ledges begin to thin out and disappear.

Water supply.—In general, this area is not yet extensively under cultivation and consequently comparatively few wells have been put down. The Osage Indians are the most primitive of all the tribes in Oklahoma. Many yet retain their tribal customs and manners of dress, and are usually known as "blanket Indians." During the last few years, however, many of the Osages have taken allotments, and the greater part of the land along the various streams has been leased to enterprising white men who are cultivating farms, often of considerable size. This is particularly the case along the valleys of Arkansas River and such minor streams as Beaver, Salt, Hominy, and Sand creeks. Except in rare instances, however, the uplands are not cultivated, and for that reason no comprehensive statements may be made regarding wells on them; but in such wells as have been put down near farmhouses and on ranches in the valleys an abundant supply of water has usually been found. There is no reason to doubt that on the uplands a satisfactory supply of water can be obtained. As is

usual in a limestone country, the water often is hard, but usually is not unfit for use. In the eastern part of the Osage country, as stated above, the rocks are chiefly sandstone and shales, and in this region the wells furnish a good supply of soft water.

Throughout the greater part of the Osage Nation are many springs of considerable size. In the eastern part of the reservation these springs flow out from under sandstone ledges, usually above shale rocks, and the water of such springs is soft. Many Indian cabins and even many farms and ranches of considerable size have been located with reference to some spring. The water in Buck, Sand, Bird, and Hominy creeks, which rise in the Flint Hills and flow east across the reservation, emptying into Verdigris River, usually comes from springs that are for the most part perennial. In the western part of the Osage Nation are also many large springs, usually issuing from under limestone ledges, and the water is consequently hard. Such creeks as Little Beaver, Big Beaver, Salt, Gray Horse, and others are fed by springs from the Flint Hills. Some of these springs are of considerable size—for instance, Big Spring, on Little Beaver Creek, 6 miles south of Maple City, Kans., has long been known as a camping place and resort. On the hill above this spring are located the famous Timbered Mounds, which are, in fact, nothing but ancient flint quarries from which Indians obtained the material for their implements.

But few wells have been reported from the Osage Nation, and because of the insufficient data no records are given.

KAY COUNTY.

Rocks and drainage.—This is the northeastern county of Oklahoma. It is limited on the east by Arkansas River and on the north by the Kansas boundary. The county is approximately 30 miles square, and is one of the most fertile in the Territory. With the exception of the portion along Arkansas River in the eastern part of the county, the topography is in general very even.

The Salt Fork of the Arkansas flows through the southern tier of townships and empties into Arkansas River in the Ponca Reservation a few miles south of the Kay County line. Tributary to the Salt Fork in Kay County are Chikaskia River, Bois d'Arc Creek, and Deer Creek, and tributary to the Chikaskia are Duck and Gypsum creeks. All of these streams have carved shallow channels in the level upland, rendering the surface in many places slightly rolling, but in only few localities are there bluffs of any considerable height.

In the eastern part of the county from the Kansas line south to Ponca City are the limestone rocks, which form the southern part of

the Flint Hills. From the level of the river to the top of the hill near Newkirk there are 6 or 8 heavy ledges of limestone varying in thickness from 5 to 30 feet.

West of the limestone country there is an area comprising the greater part of the county, in which the rocks consist of grayish or bluish shales with a few ledges of thin limestone. This area, which extends about as far southwest as Deer Creek, is the southern extension of the Marion and Wellington formations of Kansas, which in that State outcrop over several counties and extend from the top of the Flint Hills westward to the line of the red beds or Cretaceous rocks. In Oklahoma, however, these formations have but a limited areal extent, being confined to Kay County. In both Kansas and Oklahoma the shales contain extensive deposits of gypsum and salt, and one of the Oklahoma gypsum mills is located in this county.

In the southwestern part of the county, including the township west of Deer Creek and most of the regions south of the Salt Fork of Arkansas River, are typical red shales and sandstones of the red beds. Along several of the streams, particularly along the north slope of the Salt Fork, there are areas covered with Quaternary sand hills.

Water supply.—Wells have been sunk on nearly every quarter section in Kay County, with depths varying from 20 to 80 feet, and usually yield an abundant supply of water. In central and northern Kay County, in the gypsum region west of the limestone hills, the supply of water is abundant, but rather inferior in quality, being usually too hard for domestic use. In the red beds region, in the southwestern part of the county, the water usually contains more or less gypsum, although there are a number of wells which obtain water from a bed of sandstone. In these wells the water is almost uniformly soft. The best water in Kay County is found in the sand hills region, north of the Salt Fork, where the wells are usually shallow, not exceeding 20 to 30 feet in depth. In the bluffs along Arkansas River in the eastern part of the county are numerous springs, and, as is usual in a limestone region, the water from these springs is hard, though in most places not sufficiently so to render it unfit for use. There are also a number of springs of good soft water among the sand hills, particularly along the north bank of Salt Fork west of Tonkawa. Analyses Nos. 41, 42, and 43 are of water from wells, and Nos. 138 and 139 are of water from springs in Kay County.

Well records.—Of 104 wells reported from Kay County, 35 furnish soft water, 55 hard water, and 14 salty water. The average depth of the 104 wells reported was 61 feet. The list on page 162 includes records of 10 wells taken from various parts of the county, and is believed to be representative of the water conditions.

NOBLE COUNTY.

Rocks and drainage.—Noble County lies directly south of Kay County. In describing this county there will be included the Otoe and the southern half of the Ponca reservations. Arkansas River flows for 20 miles or more along the northeastern boundary of the county, forming a double oxbow bend. Across the county from west to east flow Red Rock and Black Bear creeks, both of which rise in Garfield County and empty into Arkansas River.

The rocks in the northeastern part of Noble County are largely shales and limestones, but in this region many of the ledges of limestone, which form the main part of the Flint Hills in the Osage country, finally disappear and give place to shales and sandstones. The greater part of the rocks of this county, however, particularly in the vicinity of Perry and westward, consist of typical red beds clay and sandstones. It would perhaps be correct to say that the transition from the Flint Hills and the Pennsylvanian rocks to the typical red beds takes place largely in this county. The sandstones throughout the greater part of Noble County are normally gray or brown while the shales are almost always brick red. Along the western line however, even the sandstones become red, and so continue to the western part of the Territory.

Water supply.—The water in the eastern part of Noble County, particularly in the region now occupied by the Otoe and Ponca reservations, is not particularly abundant. Wherever wells have been put down, however, a sufficient supply of water for domestic and stock use has usually been obtained. In the southern part of the county sandstone beds are abundant, and in most localities wells yield plenty of good water. In the western part the water often contains mineral salts, chiefly gypsum or salt, but there are comparatively few wells in which water is not suitable for house use. There are also springs of considerable importance in Noble County, and a number of the small creeks which are fed by them flow the year round. Analyses Nos. 52, 53, 54, 55, and 56 are of water from wells in Noble County.

Well records.—Of 29 wells reported from Noble County, 16 contained soft water, 9 hard water, and 4 salty water. The average depth was 52 feet. A list of wells from all parts of the county is given on page 166.

PAWNEE COUNTY.

Rocks and drainage.—The shape of Pawnee County, which lies immediately east of Noble, is that of a right angle triangle, of which Arkansas River on the northeastern side is the hypotenuse. The eastern end of the county extends farther east than any other part of Oklahoma except the Osage Nation. Cimarron River empties into

the Arkansas in the extreme southeastern part of the county. Black Bear Creek enters from Noble County and flows southeast to join Arkansas River. A number of small creeks tributary to the Arkansas, Cimarron, and Black Bear have cut the surface into a series of valleys and ridges, and in parts of the county the surface is uneven, high hills and steep slopes being common.

The rocks are mostly shales, sandstones, and limestones and do not differ materially from those of Osage Nation, just across the river. In Pawnee and Noble counties the Flint Hills finally lose their identity and become merged with the red beds and heavy ledges of sandstone.

Water supply.—As would be expected in a region with the geologic structure of Pawnee County, water is abundant and there is no part of the county where it is not good. Wells which usually obtain a permanent supply at moderate depths are found on practically every quarter section. In a few instances the water from the wells is salty, but such cases are rare.

Springs which usually issue from beneath ledges of limestone are common in Pawnee County, and from under several of these ledges there is almost constant seep for a distance for sometimes several miles. In other localities bold springs are common. Analyses Nos. 64, 65, 66, 67, 68, and 69 are of water from wells and No. 142 is of water from a spring in Pawnee County.

Well records.—Of 151 wells reported from Pawnee County, 94 furnish soft water, 50 hard water, 6 salty water, and 1 sulphur water. The average depth is 57 feet. The records on page 166 were taken from all parts of the county.

PAYNE COUNTY.

Rocks and drainage.—The Cimarron flows through the southern part of Payne County and across the northwest corner of the Creek country before joining Arkansas River. The largest tributary of the Cimarron in Payne County is Stillwater Creek. The smaller creeks cutting across sandstone ledges have produced the rough surface characteristic of so much of eastern Oklahoma.

The rocks of Payne County are chiefly shales and sandstones, with a few interbedded limestone layers which have persisted from the Flint Hills region. The color of the rocks in the western part of the county is normally red, although some of the sandstones are brown or gray. Farther east they are all of a lighter color, but the shales continue to be red nearly to the eastern line of the county.

Water supply.—The general conditions of water supply in Payne County do not differ materially from those in Pawnee and Noble

counties. Wells are numerous and furnish plenty of water, usually of good quality. In the western part of the county, however, where the rocks are typical red beds a considerable amount of hard water is encountered, and some wells even contain salt water. Springs are found in practically all parts of the county. Most of them, however, are nothing but small seeps, which issue from under limestone or sandstone ledges. Analyses 70, 71, 72, 73, 74, and 75 are of water from wells in Payne County.

Well records.—Of 140 wells reported from Payne County, 78 furnish soft water, 56 hard water, and 6 salty water. The average depth of the 140 wells reported is 55 feet. Records 202–211, on page 166, are from this county.

LINCOLN COUNTY.

Rocks and drainage.—Deep Fork of the Canadian flows east across the center of Lincoln County. The north line of the county approaches nearly to the Cimmaron, while part of the south boundary is North Canadian River. This stream arrangement causes two east-west divides, which pass across the county, and small tributary creeks flowing into the Cimarron, Deep Fork, or North Canadian have cut into these divides and increased by erosion the asperity of surface features. The rocks of Lincoln County are largely sandstones and shales; the shales are usually red, the beds of sandstones being often brown or gray.

Water supply.—Wells in this county obtain abundant supplies of water at depths ranging from 25 to 150 feet. Sandstone is the source of the water in the greater part of them, and most of them supply soft water. The springs of Lincoln County do not differ from those in counties farther north, where similar rocks are found. From under sandstone ledges numerous seep springs issue and in certain localities bold perennial springs are common. Over a considerable part of the county the soil is loose and sandy, and much water which under other conditions might come to the surface in the form of springs escapes in underflow. In many places where a spring reaches the surface the water soon again sinks into the sand. Analysis No. 140 is of water from a spring in Lincoln County.

Well records.—Of 58 wells reported from Lincoln County, 40 furnish soft water, 16 hard water, 1 salty water, and 1 sulphur water. The average depth of the 58 wells is 84 feet. The 10 well records on page 164 indicate the water conditions in this county.

POTTAWATOMIE COUNTY.

Rocks and drainage.—This is the southeastern county of the Territory. The North Canadian flows through the northern part, the South Canadian forms its southern boundary, and Little River

flows from west to east across the central part of the county. Numerous small tributaries to these larger streams have cut into the upland, forming low, rolling hills.

The rocks are similar to those in counties north, being chiefly sandstones and shales, normally red in color. The sandstone is loosely consolidated, and the cementing material, chiefly calcium carbonate, having been dissolved, the sand grains fall apart and form loose sand, which is blown by the wind into sand hills. This county, as well as Lincoln and Payne, lies entirely within the Sandstone Hills region of Oklahoma.

Water supply.—Wells have been put down in all parts of this county, and the water obtained from them is usually of a good quality, although in certain sections it contains gypsum and other mineral salts. In this county springs occur chiefly under three conditions—in creek bottoms, where water removes the sand down to the underlying shale; on hillsides, where the covering sand mantle is too thin to carry all the water that flows down the hill, and as seep springs, which in wet weather occur in shale beds. Analyses Nos. 76, 77, and 78 are of water from wells in Pottawatomie County.

Well records.—Of 76 wells reported from Pottawatomie County, 37 furnish soft water, 37 hard water, and 2 salty water. The average depth is 70 feet. On page 168 is the record of 10 representative wells, selected from practically all parts of the county.

CLEVELAND COUNTY.

Rocks and drainage.—South Canadian River bounds this county on the south and west; Little River, a tributary of the latter stream, rises in the county and flows east into Pottawatomie County. The eastern part of the county lies in the Sandstone Hills region and the northwestern part in the Low Plains region. The eastern part of the county is somewhat broken, as the streams that flow into Little River and South Canadian have cut rather deep valleys into the sandstones that comprise the greater part of the rocks. The divide between Little River and Canadian is generally level.

The rocks consist for the most part of red beds in which sandstone members are common in the eastern part of the county, although even here red shales make up a great part of the rocks. West of the Atchison, Topeka and Santa Fe Railway there is relatively little sandstone, and red shale makes up the greater part of the rocks. Along the north slope of the South Canadian there are areas of sand hills, probably composed of remnants of Tertiary sands.

Water supply.—In the eastern part of Cleveland County much of the water is found in sandstone, and is consequently soft. On the level divide between the rivers the water is, in general, not so good,

being impregnated in many places with mineral salts, although even here many of the red beds wells furnish pure, soft water. In the sand-hills region north of the South Canadian the water is always good. Springs are not abundant in this county; in the eastern part there are a few springs issuing from under ledges of sandstone, in which the flow, while never very strong, is constant. In the sand-hills region are a number of springs that flow the year round. Analyses Nos. 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24 are of water from wells in Cleveland County.

Well records.—Of 82 wells reported from this county, 40 furnish soft water, 33 hard water, 7 salty water, and 2 iron water. The average depth of the 82 wells was 88 feet. Records of wells in Cleveland County are given on page 158.

OKLAHOMA COUNTY.

Rocks and drainage.—The drainage of Oklahoma County is rather complex. North Canadian River flows east through it, making a large bend to the north in the eastern part of the county, but its drainage area is limited, and the four corners of the county drain into four different streams. Deep Fork of the Canadian drains the northeast part and Little River the southeast corner. South Canadian drains the southwest corner, and Chisholm Creek, a tributary of the Cimarron, heads in the northwest corner.

Oklahoma County, like Cleveland County, lies partly in the Sandstone Hills region and partly in the Low Plains region; consequently, the rocks of the eastern part of the county consist largely of red sandstones, while farther west sandstones become less abundant and shales and clays make up practically all the rocks. The eastern part of the county is more broken than the western. The headwater of Deep Fork have cut canyons into the sandstones, giving to the country the dissected surface so characteristic of eastern Oklahoma while farther west there are comparatively few forms of relief.

Water supply.—Wells in this county find water at reasonable depths. In the Sandstone Hills region the water is often soft, but farther west hard water predominates. Along the North Canadian wells in the alluvial flood plain have good water. Oklahoma County has comparatively few springs. Of these the greater part flow from the sandstone beds in the eastern part of the county, generally near one of the divides, and issuing at the head of a canyon which has been cut through the sandstone into the clay and shale below. Especially is this condition true along the canyons which empty into Deep Fork. Red beds springs occur, however, along both Chisholm and Cottonwood creeks. So far as known, there are no Tertiary springs in this

county. Analyses Nos. 57, 58, 59, 60, 61, 62, and 63 are of water obtained from wells in Oklahoma County.

Well records.—Of 36 wells reported from Oklahoma County, 25 furnish soft water, 10 hard water, and 1 salty water. The average depth is 60 feet. The 10 well records given on page 166 are believed to represent typical conditions in this county.

LOGAN COUNTY.

Rocks and drainage.—With the exception of the southeastern part of the county, the water of which flows into Deep Fork, all of Logan County is drained by the Cimarron, which flows east across the county. Skeleton Creek from the north and Cottonwood Creek from the south are the chief tributaries of this river. The surface is rather broken, particularly in the southern and eastern parts of the county.

Sandstone beds interstratified with red shales make up the greater part of the rocks of Logan County; but, as in the counties north and south of Logan, the sandstone members become thinner as the western part of the county is reached. North of the Cimarron there are belts of sand hills.

Water supply.—The wells of Logan County are in a general way similar to those in Payne and Oklahoma counties. In the sandstone ountry the wells produce soft water, while farther west the rocks ontain more mineral salts. At Guthrie there is an artesian well hich probably is supplied from a local head. There is no reason or supposing that other wells of this character will be encountered. Springs are scattered quite generally over Logan County, but are ost numerous in the sandstone region in the eastern and northeast-n parts. Many of the streams which flow into Deep Fork from e southeastern part of the county are fed by springs, and they are so abundant near Mulhall, in the northeastern part. Tertiary rings are reported from Sandy Creek, in the southwestern part of e county, and from the sand hill region north of the Cimarron. alyses Nos. 49, 50, and 51 were from wells, No. 141 from a spring, d No. 154 from a pond in Logan County.

Well records.—Of 35 wells reported from Logan County, 16 furh soft water, 19 hard water, and the average depth is 78 feet. On ge 164 are given the records of wells in various parts of Logan unty.

CANADIAN COUNTY.

Rocks and drainage.—Both North Canadian and South Canadian ers flow southeast across Canadian County, and into both of these ers empty a number of short tributary creeks. The southwestern rt of the county drains into the Washita, and the northeastern

part into the Cimarron. Nearly all the county lies in the low plains region of Oklahoma.

The rocks are chiefly red shales and clays, with occasional thin-bedded sandstones. They belong to the Permian red beds. In the northwestern part of the county occur the southern end of the Blaine Gypsum Hills in Oklahoma. In Canadian County, however, the beds of gypsum are not massive, rarely being more than 3 feet thick. North of both rivers there are deposits of Tertiary sands, these deposits being more abundant in the northwestern part of the county north of North Canadian River and west of the Chicago, Rock Island and Pacific Railroad.

Water supply.—Water is obtained at moderate depths in practically all parts of Canadian County, and, as would be expected in a region composed largely of red shales, the water is often hard, containing a large percentage of mineral salts. Among the sand hills north of the larger streams and in the alluvial flood plain along the rivers, however, the water is usually soft and pure.

There are springs of both hard and soft water in most parts of Canadian County, particularly in the Gypsum Hills region. Soft water springs come from under sandstone beds in the eastern part of the county and from Tertiary sand hills north of the streams. Cade Spring, at the Cheyenne Indian school, 4 miles north of Darlington is the most noted Tertiary spring in Canadian County.

Well records.—Of 21 wells reported from Canadian County, 11 furnish soft water, 9 hard water, and 1 salty water. The average depth is 61 feet. The water conditions of the county are set forth in the list of wells on page 158.

KINGFISHER COUNTY.

Rocks and drainage.—The entire drainage of Kingfisher County into the Cimarron, which flows from its northwest to its southeast corner. Turkey Creek from the north and Salt, Copper, Kingfisher and Walnut creeks from the south rise in other counties and cross Kingfisher before emptying into the Cimarron.

The rocks are typical red beds. Few sandstones are found, and the rocks consist largely of soft red shales. In the extreme southwestern part of the county are the Blaine Gypsum Hills, composed of masses of white gypsum. North of and parallel to Cimarron River is a row of Tertiary sand hills from 3 to 10 miles wide. The county is all in the Low Plains region of Oklahoma.

Water supply.—The greater part of the water of Kingfisher County comes from the red beds and contains a considerable percentage of mineral salts, chiefly calcium sulphate. Wells are found in all parts of the county, and it is rare that an abundant supply of water is not

found at a reasonable depth. Among the sand hills north of the Cimarron wells are usually shallow and yield soft water.

The best springs of Kingfisher County are found in the sand hills region north of the Cimarron. These springs are larger than those in Logan, the next county east, and being sand springs, consequently furnish soft water. Both in the flat region south of the Cimarron and among the Gypsum Hills in the extreme southwestern part of the county there are a few hard-water springs. Analyses Nos. 44, 45, 46, and 47 are of water from wells in Kingfisher County.

Well records.—Of 38 wells reported from Kingfisher County, 23 furnish soft water, 13 hard water, and 2 salty water, and the average depth is 36 feet. The 10 well records given on page 162 represent the conditions in Kingfisher County.

GARFIELD COUNTY.

Rocks and drainage.—Garfield County drains in three directions—south into the Cimarron, north into Salt Fork, and east into the Red Rock and Black Bear creeks, tributaries of the Arkansas. It has no large river. The surface of the greater part of the county is flat, monotonous prairie, while along the large creeks the bluffs are low and inconspicuous.

Red beds make up the greater part of the rocks of the county, and of the red beds red shales and clays constitute the greater proportion. A few beds of sandstone, however, outcrop in the eastern part of the county, but they are so infrequent as to give scarcely noteworthy relief. The southwestern fourth of the county contains more or less conspicuous deposits of sand, approaching, in localities, sand-hill conditions. Most of the shallow creek bottoms, and some portions of the uplands, are covered with a blanket of Tertiary sand.

Water supply.—Water in the red beds of Garfield County is abundant; it varies from that which is pure and soft to water so full of gypsum and other salts as to be unfit for use. Wells are found everywhere, and water is encountered at reasonable depths. In the sand-hills region good water is abundant, and in many parts of the county upland wells or those along prairie streams yield soft water.

Springs, which are most abundant in the sand-hills region in the central and southwestern parts of the county, supply good water, usually in considerable quantities. The water from many of these springs, however, soon sinks again into the sand, and in some instances reappears farther downstream as another spring. In the red beds region springs are found, but in general these springs rarely furnish sufficient water for domestic use. Strong red beds springs are, however, not unknown, and in some of them the water is of good quality. Water analysis No. 38 is from a well in Garfield County.

Well records.—Of 104 wells reported from Garfield County, 4 furnish soft water, 46 hard water, 15 salty water, 1 sulphur water and 1 iron water. The average depth is 42 feet. Typical water conditions are shown by the well records on page 160.

GRANT COUNTY.

Rocks and drainage.—This county lies west of Kay, its north line touching Kansas, and is entirely within the Low Plains region of Oklahoma. The drainage is all into the Salt Fork of the Arkansas, which flows east across the southern part of the county. The chief tributaries in the county are Deer, Cottonwood, Pond, and Sand creeks, all of which enter Salt Fork from the north. The surface is smooth or rolling, very few conspicuous relief forms being found.

The rocks consist chiefly of red beds and Tertiary deposits. The red beds, which belong to the Enid formation and constitute the bed rock throughout the county, consist largely of sandstones and clays, of which the latter form the major part. Few ledges of sandstone hard enough for building purposes are found in Grant County. Sand hills are found along the Salt Fork, principally on the north side of the streams, in an east-west belt from 5 to 15 miles in width. A considerable portion of the upland is covered also with sand and loam of Tertiary or Quaternary age.

Water supply.—Wells may be found on nearly every quarter section in Grant County, and in most cases the water is both abundant and wholesome. Among the sand hills this is almost universally true. In a number of cases where the rocks are chiefly red beds, wells put down in the sand and gravel deposits along some prairie creek have plenty of good water. As an example of this fact may be given the city well at Medford. After trying in vain to secure good water in the red beds under the city a well was dug in the bed of a small stream a mile distant and an abundant supply was obtained. There are wells in which the water contains gypsum, salt, soda, magnesia, or some other such substance, but in the majority of them such is not the case.

Springs, which are abundant in most parts of the county, issue usually from sand deposits, and almost without exception furnish soft water. The streams north of the Salt Fork are fed in a large part by bold, perennial Tertiary springs. There are also springs in the red beds in Grant County, but like those of this formation in adjoining counties, they are usually unimportant. Analyses Nos. 39 and 40 are of water from wells and 152 and 153 of water from ponds in Grant County.

Well records.—Of 54 wells reported from this county, 27 furnish soft water, 18 hard water, and 9 salty water. The average depth of

the wells recorded is 33 feet. The well records on page 162 show the characteristic water conditions in the county.

WOODS COUNTY.

Rocks and drainage.—With the exception of the southwestern and northwestern parts, which are included in the Gypsum Hills region, Woods County lies within the Low Plains region of Oklahoma. Three of the larger streams of the Territory flow across the county—the Salt Fork, which flows across the northern part; the Cimarron, which crosses the county south of the center, and the North Canadian, which touches the extreme southwest corner. Sand, Mule, and Medicine creeks from the north and Clay Creek from the south are the chief tributaries of the Salt Fork, which receives the drainage of perhaps one-third of the county. Of the smaller streams emptying into the Cimarron, Eagle Chief and Indian flow from the north, and Cottonwood, Skull, Barney, Greaver, Main, and West creeks, all of which take their rise among the Gypsum Hills, from the south. The Cimarron and its tributaries drain more than half of Woods County. North Canadian River, in the southwestern part, receives the drainage of but a small area, perhaps not to exceed two townships in all, no creeks emptying into it in this county.

The rocks of the county consist largely of red beds clays and Tertiary sand. The Blaine Gypsum Hills, which it will be remembered are a part of the Permian red beds, extend parallel to and south of the Cimarron across the southwestern part of the county, and appear again in the northwestern part, near the Kansas line. In the Gypsum Hills the rocks consist chiefly of red shales with interbedded deposits of massive white gypsum and dolomite. With the exception of the formations in the Gypsum Hills, the rocks of the red beds do not differ materially from those farther east, being composed chiefly of red shales, with a few inconspicuous sandstone members. The sand hills, also, are like those already discussed, the only difference being that toward the western part of the Territory the Tertiary deposits are more pronounced and the sand-hills districts more conspicuous.

The alternation of surface deposits of sand hills and red beds gives rise to a peculiar zonal distribution of formations noticeable in many parts of western Oklahoma, but nowhere better exemplified than in Woods County. It may be illustrated as follows: In passing from the Kansas line to the southwestern part of the county one will cross successively a number of these various lithologic zones. On the Kansas line is found the typical red shales; a few miles south, north of the Salt Fork, one enters the sand-hills region, a strip of country here about 10 miles wide, that continues south to the river. South

of the Salt Fork the red beds again appear and continue for 20 miles or more across the divide between the waters of the Salt Fork and the Cimarron, until finally the sand hills north of the latter stream begin to appear. This belt of sand hills is 10 to 15 miles across. Then comes the red beds slope south of the Cimarron, including the Gypsum Hills, while on top of these hills and still farther southwest lie the sand hills on the north slope of the North Canadian.

Water supply.—The water conditions follow closely the lithologic conditions in this as in other Oklahoma counties. In red beds areas the water is abundant, but often hard; in the sand hills it is both abundant and soft, and in the region around the Great Salt Plain, in the eastern part of the county, water from wells is often salty, while among the Gypsum Hills and in some other parts of the county gyp-

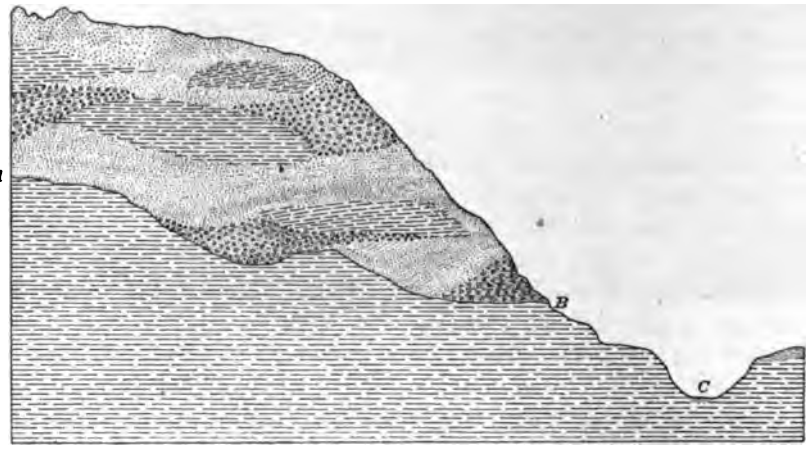

FIG 30. Section at Cleo Springs, Okla. A–B, red beds–Tertiary unconformity; B, spring; C, bed of Eagle Chief Creek.

sum water is found, often of such a character as to render it unfit for use. The water is about equally divided between hard and soft.

Woods County has an abundance of springs, most of which are located in regions of Tertiary rocks. North of the Salt Fork there are scores, perhaps hundreds, of strong perennial springs, and among the sand hills north of the Cimarron they are equally abundant. Cleo Springs (see fig. 30), near the mouth of Eagle Chief Creek, and Elm Springs, from which the city of Alva obtains its water supply, may be cited as examples of Tertiary springs. There are springs in the red beds in Woods County, and some of them have a considerable reputation. In the vicinity of the Salt Plains there are a number of salt springs, although none of them are of size comparable with the salt springs in Woodward, Blaine, or Greer counties. Clay Creek is fed largely by springs, Timberlake Springs were famous long before the country was open to settlement, Whitehorse Springs supply the

whole township with water, and among the Gypsum Hills are a number of perennial springs. Analyses Nos. 79, 80, 81, 82, 83, and 84 are of water from wells, and Nos. 143, 144, 145, 146, 147, 148, and 149 are of water from springs in Woods County.

Well records.—Of 304 wells reported from Woods County, 148 furnish soft water, 138 hard water, 15 salty water, and 3 sulphur water. The average depth of the 304 wells reported is 46 feet. The well records on page 170 show the water conditions in various parts of this county.

BLAINE COUNTY.

Rocks and drainage.—Cimarron, North Canadian, and South Canadian rivers flow southeast across Blaine County. The Cimarron touches the northeast corner, the South Canadian flows for 15 miles through the southwest corner, while the North Canadian enters at the northwest corner and flows diagonally across to the southeast corner. While the Cimarron flows but such a short distance through the county, it receives nearly half of the drainage. This is due to the fact that the valley of the Cimarron in Oklahoma is from 200 to 300 feet lower than the valley of the North Canadian. Several creeks of considerable size, of which Salt Creek is the largest, rise among the Gypsum Hills and flow northeast into the Cimarron. The North Canadian receives a few short tributary creeks, most of which enter from the south, and drains a strip of country about 20 miles wide. An area of perhaps 150 square miles in the southwestern part of the county is drained by the South Canadian.

The rocks of Blaine County consist of Permian red beds and Tertiary and Pleistocene sands and alluvium. The northeastern part of the county is included in the Low Plains region, and the remainder of the county in the Gypsum Hills region. The Blaine Gypsum Hills, which are parallel to and 10 to 15 miles south of the North Canadian, rise like a wall 200 to 300 feet above the level prairie to the east. Red shales make up not only this flat prairie country, but also the greater part of the slope of the Gypsum Hills, while on top of these hills and between the bluffs and the North Canadian lie extensive sand hills. Southwest of this river red beds again appear, the rocks consisting largely of the Whitehorse and Day Creek members of the Woodward formation. On Red Hill, 8 miles northwest of Geary, is one of the best exposures of Day Creek dolomite in the Territory. Sand hills occur again along the north slope of the South Canadian, and beyond that stream red beds are again found.

Water supply.—The water of Blaine County varies with the locality. In the sand-hills region it is good. East of the Gypsum Hills, in the red shale country, the water from wellsc ontains a comparatively

large percentage of mineral salts, chiefly gypsum. South of the North Canadian, also, the water is often not suitable for use. North of both Canadian rivers, in the sand-hills country, wells usually encounter good soft water at moderate depths.

Springs are common among the Gypsum Hills, issuing generally from above shales and beneath gypsum ledges, but in such a case the water is often so strongly impregnated with gypsum as to be unfit for use. In the bottom of one of the deep canyons among these hills, 4 miles west of Ferguson, are a number of springs of strong salt water. The waters of these springs unite and form a plain, which extends for several miles along Salt Creek. There is enough salt water going to waste in this region alone to make sufficient salt to supply several States. The best soft-water springs in Blaine County are found among the sand hills north of the streams, and these springs as in other counties in which sand hills are found, are generally strong and flow the year round. As an example of the use to which a Tertiary sand-hills spring may be put may be cited the case of the Rubey Stucco-Plaster Company, at Ferguson, Okla. The cement mill is located in a canyon at the base of the Gypsum Hills and good water was not available. A pipe was laid from a spring located on a hill at an elevation of 200 feet above the plant and 2½ miles distant, and an ample supply of water was obtained for boiler and domestic use. Analyses Nos. 3, 4, and 5 are of water from wells in the red beds at Geary, Blaine County, and Nos. 150 and 151 are of water from salt springs at the head of Salt Creek, 4 miles west of Ferguson, Blaine County.

Well records.—Of 108 wells reported from Blaine County, 63 furnish soft water, 39 hard water, 6 salty water, and the average depth is 60 feet. The 10 records on page 156 were taken from all parts of the county and represent the general water conditions.

CADDO COUNTY.

Rocks and drainage.—Washita River flows east across the central part of this county, while the South Canadian touches the northeast corner, and Cache Creek, a tributary of the Red River, drains several townships in the southern part. The chief tributaries to the Washita in this county are Sugar and Cobb creeks, both of which enter from the north.

Red beds constitute the greater part of the rocks of Caddo County, and, as in other parts of the Territory, sandstones and clay shales make up the greater part of the red beds. In Caddo County, however, the sandstone greatly predominates. The Whitehorse member of the Woodward formation thickens in this region, giving rise to a series of fine-grained red or grayish sandstones, often weathering

into conspicuous buttes, which are typically exposed on the high divide between the Washita and South Canadian southwest of Bridgeport. (See Pl. X, *A*.) In the southern and western parts of the county the deposits of Greer gypsum outcrop in conspicuous ledges on hilltops. So far as known there are no extensive deposits of Tertiary sand in Caddo County. It is true that there are sand hills, but they are composed largely of sand of disintegration from the Whitehorse. In the southwestern part of the county there are hills composed of Arbuckle limestone, the northern extension of the Wichita uplift.

Water supply.—The water in Caddo County is generally good. Wells in the sandstone usually secure soft water, although in certain parts of the county, notably on the divide between the Canadian and the Washita, the depth to water is often as much as 200 feet, but the water when found is almost uniformly pure and wholesome. In the gypsum region hard water predominates. Springs are not uncommon in Caddo County, although over considerable areas strong springs are rare. The water which percolates through the fine-grained sandstone comes out as seeps along the side of a hill or in the head of a narrow canyon. In the limestone hills are a number of strong springs which issue from limestone rocks. Analysis No. 6 is of water from a well at the Anadarko brickyard.

Well records.—Of 75 wells reported from Caddo County, 62 furnish soft water and 13 hard water. The average depth is 88 feet. The 10 well records on page 156 show the character of the water in the various parts of the county.

COMANCHE COUNTY.

Rocks and drainage.—With the exception of small areas in the northwestern and northeastern corner, which drain into the Washita, Comanche County is drained by Red River. Beaver, Cache, Deep Red, and other creeks are the principal tributaries.

The main range of the Wichita Mountains lies in the northwestern part of Comanche County. These mountains consist largely of igneous rocks—gabbro, porphyry, and granite. North of the main range is a row of limestone hills containing rocks of Cambrian and Ordovician age. The rocks over the remaining portion of the county are chiefly red bed and shales, except along the north bank of Red River, where there is a district covered with sand hills.

Water supply.—Comanche County is well watered. Wells which have been put down in the red beds encounter water, usually of good quality, at moderate depths. Springs are found in most parts of the county. Those in the red beds are usually weak and uncertain, often being nothing but seep springs. Among the granite and lime-

stone mountains, however, springs are abundant, and the perennial streams issuing from these mountains are fed by the springs. The springs among the limestone rocks contain a considerable amount of calcium carbonate, while the granite springs yield very pure water. Analyses Nos. 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, and 36 are of water from wells; Nos. 136 and 137 of water from springs, and Nos. 134 and 135 are of water from creeks in Comanche County.

Well records.—Of 25 wells reported from Comanche County 18 furnish soft water, 7 hard water, and the average depth is 32 feet. Typical water conditions are given in the 10 well records on page 158.

KIOWA COUNTY.

Rocks and drainage.—The North Fork of Red River forms the western line of Kiowa County, and the Washita flows through the northeast corner. The drainage of the greater part of the county is carried by Elk and Otter creeks, which flow south into North Fork, and Rainy Mountain Creek, which flows northeast into the Washita. The rocks consist chiefly of red beds and granite, the latter rock forming the western extension of the Wichita Mountains. The red beds consist largely of typical red clay shale, which, in localities near the mountains, grades off into conglomerate. In the northern part of the county are a few ledges of dolomite and sandstone, and along North Fork are localities in which sand hills are found.

Water supply.—Water is obtained from wells in practically all parts of the county. Its quality varies, being usually better south of the mountains than north. Springs are found among the mountains, and the water there obtained is pure and sweet; Otter Creek is fed largely by springs of this kind. Red beds springs are also known, but as a rule the amount of flow from springs of this kind is not great. Analysis No. 48 is of water from a well at Snyder.

Well records.—Of 35 wells reported from Kiowa County, 21 furnish soft water, 12 hard water, and 2 salty water. The average depth is 29 feet. The water conditions in various parts of the county are shown by well records on page 164.

GREER COUNTY.

Rocks and drainage.—Greer, the southwestern county in Oklahoma, lies southwest of the North Fork of Red River, and all the drainage is into one of the four branches of the Red—North Fork, Elm Fork, Salt Fork, or South Fork. The surface is generally level with the exception of canyons in the Gypsum Hills along parts of Elm Fork and Salt Fork. The extreme western extension of the Wichita Mountains lies west of North Fork of Red River, in the northeastern part of the county.

The rocks are mostly red beds, with red shale predominating. A very considerable part of the county is underlain with gypsum, which in places outcrops along the sides of various streams. Sand hills occur along some parts of both the North Fork and the South Fork.

Water supply.—As Greer County has more gypsum than any other two counties in the Territory, one would expect to find hard water. Wells frequently encounter beds of gypsum at depths ranging from 20 to 100 feet, and in such cases the water often found just beneath the gypsum partakes of the quality of that mineral. The springs of Greer County issue usually from beneath gypsum ledges along bluffs, although prairie springs are not unknown. In the western part of the county, within 5 miles of the Texas line, there are two salt plains, each formed from salt springs which issue from the bottoms of canyons carved into the Gypsum Hills south of Elm Fork. For a number of years salt has been manufactured on both these plains. Sand-hills springs are found near some of the streams and at Granite there is a sulphur spring. In general, the water of Greer County is abundant in quantity but rather undesirable in quality.

Well records.—Of 152 wells reported from Greer County, 26 furnish soft water, 109 hard water, and 16 salty water. The average depth is 70 feet. The well records on page 162 show the varying character of the water of this county.

WASHITA COUNTY.

Rocks and drainage.—Washita River flows southeast through the eastern part of the county and receives more than three-fourths of its drainage. The southwestern corner is drained by Elk Creek, a northern tributary of North Fork of Red River. In the eastern part on both sides of the Washita there are considerable ledges of gypsum, while farther west sandstone of the Quartermaster formation prevails. On the divide between Elk Creek and the Washita, in the western part of the county, there are sand hills. Red beds constitute practically all the rocks of the county.

Water supply.—In the eastern part of Washita County wells often pass through gypsum and obtain a supply of hard water directly beneath a bed of it. One such deposit, penetrated in a well near Seger, is reported to be 115 feet thick, the thickest so far known in the Territory. In the western part of the county good water is obtained from the Quartermaster, although the supply is sometimes limited.

Springs in Washita County are principally of two kinds—gypsum springs and sandstone springs. In the eastern part of the county the water from gypsum springs is not always good; water from the sandstone springs in almost every instance is soft and wholesome,

although occasionally limited in amount. Many of the gypsum springs issue as bold streams from beneath heavy ledges, while the sandstone springs usually occur as seeps from the fine-grained sandstone along the heads of prairie canyons.

Well records.—Of 60 wells reported from Washita County, 43 furnish soft water, 13 hard water, and 4 salty water. The average depth is 66 feet. The well records on page 168 show the water conditions in this county.

CUSTER COUNTY.

Rocks and drainage.—The greater part of the drainage of Custer County enters Washita River, which flows southeast across the county. South Canadian River, however, crosses the northeast corner and Deer Creek, a tributary of that stream, drains the eastern part. Beaver, Barnitz, Turkey, Quartermaster, and other creeks are tributary to the Washita. The surface is rolling, the streams having cut rather deep valleys into the upland.

The rocks are chiefly of red-beds shales and clays. In the western part of the county the Quartermaster formation is well developed and in the eastern and central parts are considerable deposits of gypsum. Small areas of Comanche Cretaceous rocks are found in Custer County, but are of no importance as far as the water supply is concerned. Sand hills are rare in Custer County.

Water supply.—The character of the water is such as would be expected in a region of red-beds shales and gypsums, generally containing mineral salts in greater or less amounts. Wells usually obtain an abundance of water, however, and there is very little of it that may not be used. Springs are also found, but not in large numbers. In the Quartermaster sandstone, in the western part of the county, springs typical of that formation occur—weak seep springs which issue usually from the head of a small canyon that has been cut into the soft sandstone. The water from these springs is uniformly good.

Well records.—Of 125 wells reported from Custer County 44 furnish soft water, 80 hard water, and 1 salty water. The average depth is 74 feet. Typical conditions are shown by the well records given on page 158.

DEWEY COUNTY.

Rocks and drainage.—The South Canadian flows east through this county in a series of oxbow bends, while the North Canadian crosses the northeast corner. Perhaps three-fourths of the drainage empties into the South Canadian, although the creeks tributary to this stream are usually short and unimportant.

The rocks are largely red beds. Sand hills occur north of the

South Canadian. Among the red beds sandstone is rare, the greater part of the rock consisting of red shales interspersed with beds of white gypsum.

Water supply.—Wells are common in Dewey County, and the water, which varies much in quality, is usually plentiful. Springs are found chiefly among the sand hills, where the water is both abundant and pure, although red beds springs which furnish hard water are not unknown. Analysis No. 37 is of water from a well in Dewey County.

Well records.—Of 123 wells reported from Dewey County, 21 furnish soft water and 102 hard water. The average depth is 93 feet. The 10 records on page 160 indicate the varying conditions of the water of this county.

ROGER MILLS COUNTY.

Rocks and drainage.—The North Fork of Red River forms the southern boundary of this county, and the Washita flows across its northeastern corner. A number of short creeks emptying into these rivers drain the entire county. Except a part of the divide between the Washita and North Canadian rivers, in the western part of the county where Tertiary sand hills are found, the rocks consist largely of red beds which cover practically the entire county. The greater part of these belong to the upper Quartermaster formation of the Permian and consist of fine-grained sandstone and shales. In the extreme southern part of the county, along the North Fork of Red River, gypsum ledges are exposed along a bluff nearly 200 feet high and 10 miles long, one of the finest exposures known in the Territory.

Water supply.—With the exception of the southeastern part of the county, in which gypsum water is found, soft water predominates throughout Roger Mills County. Wells in the Quartermaster formation usually secure good water, although in limited amounts, while in the sand hills water is both abundant and wholesome. Springs which occur in the Quartermaster are usually rather weak seep springs, but often furnish sufficient water to supply a farm with domestic and stock water. In the southern part of the county are a number of salt springs, while in the western part Tertiary springs are not unknown, and some of them furnish large amounts of water.

Well records.—Of 47 wells reported from Roger Mills County, 27 furnish soft water and 20 hard water. The average depth is 60 feet. Characteristic water conditions are shown in the 10 records on page 168.

DAY COUNTY.

Rocks and drainage.—The South Canadian has cut a broad canyon through this county, swinging from north to south in a series of ox-bow bends, and across the southwestern corner flows the Washita, here but a small creek. The drainage is into these two rivers.

Red clay and sandstones of Permian age, which form the bed rock, and considerable deposits of Tertiary sand and clays on the uplands, particularly in the region north of South Canadian River, constitute the rocks of Day County. The valley of the South Canadian has cut its way through this upper sand and clay formation into the red-beds clays and sandstones below. North of the Canadian, as well as in the region between this river and the Washita, in the southwestern part of the county, are large areas of sand hills, while in the southeastern part there are extensive deposits of gypsum among the red beds.

Water supply.—In the sand hills soft water is found in all the wells, and as the area covered by these hills is larger than that occupied by the red beds, it follows that in this county the water is usually good. Springs are found in both the sand-hills and the red-beds areas, the former being usually strong and furnishing good water, while the red beds springs are usually weak and the character of the water often unsatisfactory.

Well records.—Of 28 wells reported from Day County 21 furnish soft water and 7 hard water. The average depth is 84 feet. Typical records of the wells of this county are given on page 160.

WOODWARD COUNTY.

Rocks and drainage.—Woodward County is drained by Cimarron and North Canadian rivers. The former stream enters the northwest corner from Beaver County, flows southeast for 10 miles, passes into Kansas, and after flowing a distance of 25 miles in that State, again flows into Woodward County and continues in a southeast course for 40 miles or more before reaching Woods County. North Canadian River is formed by the junction of Beaver and Wolf creeks, which unite at old Fort Supply, near the center of the county, Beaver Creek flowing southeast and Wolf Creek northeast to form this junction. The chief streams flowing into the Cimarron in Woodward County are Doe, Chimney, Sand, Long, Traders, and Buffalo creeks from the south, and Anderson, Indian, Whitehorse, and Redhorse creeks from the north, all of which rise in the Gypsum Hills. Neither North Canadian River nor Beaver Creek have any tributaries of importance emptying from the north in Woodward County for the reason that the north slope of these streams is covered with sand hills; Kiowa, Otter, Clear, Indian, and Persimmon creeks are south-

ern tributaries to these streams, while Wolf Creek has a number of smaller creeks emptying from both north and south.

In Woodward County red beds are exposed along the streams, while Tertiary sand covers the uplands. Along the Cimarron and its tributary creeks beds of gypsum outcrop, and the entire valley in Woodward County is but a broad canyon cut into the Gypsum Hills. Along the North Canadian and Beaver Creek red beds are exposed, especially on the south side of the stream, but on Wolf Creek the red beds are mostly hidden and only Tertiary rocks are found. All the divides in Woodward County, as well as the north slope of the North Canadian and Beaver Creek, are covered with sand hills or consist of level upland capped by Tertiary rocks.

Water supply.—Along the Cimarron and south of North Canadian River the water is usually obtained from red beds, and in consequence is usually not good. The water from the red clay is sometimes good, but more frequently it carries so much mineral salts as to be unsuitable for house use, but on the uplands and the north slope of the North Canadian wells put down in the Tertiary formations secure an abundance of good water. On some of the uplands the wells are 200 feet deep or more, but the average depth of the wells of this kind is perhaps not more than 75 feet.

Springs occur both in the red beds and Tertiary formations. Among the Gypsum Hills along the Cimarron springs issue sometimes from beneath heavy ledges of gypsum in which the water contains large amounts of calcium sulphate in solution. In the northern part of the county there are two regions of salt springs, the largest of which includes a plain 8 miles long and 2 miles wide, from which flows a stream carrying approximately 2 second feet. The Tertiary springs of Woodward County are among the finest in the Territory. The Moscow Springs on the North Canadian have long been famous, and the Bent Canyon Springs, 20 miles north of Woodward, form a veritable oasis. Old Fort Supply was supplied with water carried in pipes from a Tertiary spring 3 miles distant, and Woodward, the county seat, obtains its water supply from Tertiary rocks. Analysis No. 85 is of water from a well in Woodward County.

Well records.—Of 53 wells reported from Woodward County, 37 furnish soft water, 15 hard water, and 1 salt water. The average depth is 56 feet. The well records on page 170 show the typical water conditions in this county.

BEAVER COUNTY.

Rocks and drainage.—Beaver County (formerly known as "No Man's Land" or the "Neutral Strip") extends from the one hundredth to the one hundred and third meridian, a distance of 165

miles west of the main part of Oklahoma. Its width is 35 miles. It is a typical part of the high plains, apparently flat and level as a floor, but in reality sloping from an altitude of over 4,500 feet at the New Mexico line to about 2,000 feet in the eastern part of the county.

Across this county Cimarron River and Beaver Creek flow from west to east. The Cimarron flows across the northwestern part of the county for 50 miles, then goes on a long excursion through Colorado and Kansas and returns to Beaver County 25 miles west of the eastern line of the county. Except for a distance of 15 miles where the stream bends south into the Panhandle of Texas, Beaver Creek flows across Beaver County from end to end. Both of the streams have carved valleys averaging 150 feet in depth and 3 miles in width, and tributary creeks are now at work dissecting the high table, but at the present time have scarcely more than commenced their task. Such creeks as Duckpond, Clear, Palo Duro, Coldwater, and others emptying into Beaver Creek from the south have their rise in Tertiary springs and are practically perennial streams.

With the exception of small areas of red beds along the south bank of the larger streams and some outcrops of Cretaceous rocks, particularly in the extreme western part of the county, practically all the surface rocks of Beaver County consist of formations of Tertiary age, which form a deposit sometimes as much as 400 feet thick above the subjacent red beds. Along the streams these Tertiary rocks have been weathered away and form sand hills, but on the uplands the surface is hard and firm.

Water supply.—Beaver County has good water. Wells on the upland rarely fail to obtain an ample supply of pure, wholesome water, although the depth of the well, often from 100 to 250 feet, renders the water difficult to draw; accordingly windmills are in almost universal use, both on ranches and near farm houses. There are a few places along the south side of Beaver and Cimarron where water is obtained in the red beds, but this is uncommon.

Springs are found in Beaver County usually issuing from Tertiary rocks, and as is the usual case the water from these springs is always good. Beaver Creek and its tributaries, perennial streams, are fed by springs from the Tertiary.

In the Dakota sandstone region, in the western part of the county, there are both wells and springs which furnish soft water, although the Dakota in this region does not supply as much water as in Kansas and Nebraska. Analyses Nos. 1 and 2 are of water from wells in Beaver County.

Well records.—Of 29 wells reported from Beaver County 19 furnish soft water and 10 hard water. The average depth is 110 feet. The

varying character of the water conditions is shown by the 10 well records on page 156.

IRRIGATION.

GENERAL STATEMENT.

Irrigation in Oklahoma has met with considerable indifference, or even open opposition, on the part of many of the people. The western part of the Territory, in which irrigation is most needed, has been settled mainly during the last five years, and in that time the rainfall has been greater than the average, and the crops have been abundant. There is a general impression that an acknowledgment that irrigation is needed will be detrimental to the interests of the Territory, and for this reason in many places the matter has usually met with a cold reception. During the last few months, however, public opinion has in a large measure undergone a change, and communities that formerly scouted the idea are now asking how such operations may be brought about.

In Oklahoma water for irrigation may be obtained from rivers, from reservoirs, from springs, and from wells. These various sources will be discussed in the order named.

IRRIGATION FROM RIVERS.

As has been stated in another part of this report, seven rivers flow southeast across Oklahoma, but for the greater part of the year many of these streams carry comparatively little water. Most of them also have sandy banks, and for that reason ditches leading across the bottom lands would lose much of their water by seepage or would soon become sand choked. In a number of places where dams have been thrown across small streams and the channel diverted into ditches it is necessary to remove the silt from the ditch every few months or to construct a new one, but in other cases where there is no sand to obstruct the ditch it remains open from year to year.

It must be remembered also that while the normal flow of Oklahoma streams is not great, they are all subject to sudden and rapid rises. The South Canadian, Red, and Cimarron rivers, in particular, often rise 10 feet or more in an hour and remain bank-full for several days, when the water gradually subsides and the channel may be practically dry for weeks. These sudden rises are often sufficient to tear out any dams such as have heretofore been constructed. On account of the broad and shallow valleys, the depth to bed rock, and the scarcity of building material, masonry dams are practically unknown, and those constructed have been of piling, plank, logs, loose rock, earth, brush, etc. (See Pl. XXI, *B*.)

Along Cimarron River and Beaver Creek, both of which are sand-

filled, and often sand-choked, irrigation has been carried on for a number of years. These streams have both been carved out of the level Tertiary upland, and both have in many places cut entirely through this surface formation into the subjacent red beds. Along Beaver Creek the red beds occur almost continuously on the south bank of the stream as far west as the mouth of Palo Duro Creek, while on the north side of the creek there are sand hills which extend 5 to 10 miles from the river. In other words, in eastern Beaver County are exhibited the phenomena so often observed along the rivers farther east, viz, a strip of sand hills north of the stream and a row of red beds canyons south of it. The amount of water in Beaver Creek varies greatly at different points and at different times of the year, so that any estimates as to amount of flow, unless based on data collected through a series of years, would be misleading. Such tributaries as Kiowa, Coldwater, and Palo Duro carry nearly as much water as the main stream at the point where they join Beaver Creek.

There are numerous small irrigation plants all along the streams of Beaver County, where rude dams of logs, earth, or loose rock have been built across the creeks and the water diverted from the channel and carried out over the bottoms to irrigate small fields and gardens. In times of flood these frail structures are washed out and often not rebuilt for several months. One of the better class of stone dams was washed out during the flood in May, 1903, and had not been rebuilt the following August. It is safe to estimate that at least one dam is present every 5 miles along Beaver and its larger tributaries as far west as Guymon. It is the universal testimony of persons living along the stream that the water taken out for irrigation does not sensibly diminish the flow, and the explanation given is that springs come in all along the bed of the stream. It is very probable, however, that this is due largely to the fact that much of the water seeps back into the channel and the stream is thereby replenished.

The character of Cimarron River in Beaver County does not differ from that of Beaver Creek. Both these streams have cut channels into Tertiary rocks, and in places into the red beds below, and both are fed at least in part by Tertiary springs.

The most successful irrigation plant in this region is just across the Kansas line near Englewood, Clark County, Kans., but the water comes from the Cimarron, in Oklahoma. The following description of this plant is taken from the report of Mr. W. G. Russell:[a]

The principal irrigation development in this part of the country has been carried on by C. D. Perry, of Englewood, Kans. About fourteen years ago he constructed a ditch from the Cimarron River to irrigate his lands in Kansas.

[a] Russell, W. G., First Ann. Rept. Recl. Service, U. S. Geol. Survey, 1903, p. 271.

He built a sheet pile dam across the channel, consisting of 2-inch piling driven to a depth of about 12 feet in the sand. The tops were held in line by two walings fastened with three-eighth inch bolts through the piling and both strips. This ditch was 8½ miles long and had a capacity of about 14 second-feet. It was not well built and was difficult to maintain. The total cost was nearly $10,000. The floods tore out a considerable portion of the dam, filled the channel with sand, and made a new channel, passing around the remains of the dam.

A new ditch was built by Mr. Perry, with head-gates lower down the stream. Instead of a dam for diverting the water, he constructed a wooden stave pipe, 30 inches in diameter, sunk in the sand, extending from the headworks diagonally upstream. This was 900 feet long and was planned to extend a mile or more. The underside of the pipe had perforations through galvanized sheet iron, intended to admit the water. The pipe was partly washed out before it was tested and the remaining portion filled with sand. Water was obtained, however, through a ditch heading at a brush dam below the pipe. The ditch now in operation is 7 miles long and cost nearly $3,000, including the wooden stave pipe. It is successful and discharges at the lower end into the old ditch. Experiments for obtaining the so-called "underflow" could probably be made at this locality with good chances for success.

Between Englewood, Kans., and Kenton, Okla., are a number of small plants where water is taken from the river by means of dams of stone, earth, or logs, and west of Kenton practically all the water is taken from the Cimarron and its tributary creeks and used for irrigation. Pl. XXI, *B*, shows a log-and-earth dam on the upper Cimarron.

Along Wolf Creek, in Woodward County, and certain branches of Washita and Red rivers small irrigation plants have been erected from time to time, but the same conditions exist as in Beaver County, and the temporary dams are usually washed out by every flood, and no great importance can be attached to these irrigation systems.

One fact regarding irrigation from Oklahoma rivers remains to be mentioned, namely, the character of the water. Cimarron, Salt Fork, and North Fork of Red River drain regions of salt springs which render the water too salty to be of any use for irrigating purposes. Salt Fork crosses the Great Salt Plain in eastern Woods County, and below that point its waters contain a considerable percentage of salt. Cimarron River flows through two salt plains in northern Woodward County and receives the drainage of the Blaine County salt plain. The salt plains of Roger Mills and Greer counties are drained by North Fork of Red River, and the water of that stream below the mouth of Elm Fork is very salty. Besides the cases mentioned, the water of the other Oklahoma streams is suitable for irrigation.

IRRIGATION FROM RESERVOIRS.

The greatest difficulty in the construction of large reservoirs in Oklahoma is that so few available sites exist. All of the larger

streams of the Territory flow for practically all their course through broad and shallow sand-filled channels. There are a comparatively few localities where streams flow through narrow gorges and masonry dams might be constructed. Of these localities the most satisfactory that have so far been examined are located in the Wichita Mountains. In October, 1903, the writer, in company with Mr. Bailey Willis, of the United States Geological Survey, visited the most available of the sites in these mountains. The following descriptions are from Mr. Willis's report:

MEDICINE BLUFF SITE.[a]

In sec. 7, T. 3 N., R. 12 W., the valley of Medicine Bluff Creek is an extensive bottom land, approximately from 1 to 1½ miles wide 60 feet above the stream level. The stream itself has moderate fall. Near the south line of the section the valley narrows to a canyon 75 feet deep and 400 feet wide between steep walls. Beneath the wider valley the rock is rather impervious red shale and sandstone; in the canyon it is granite, more or less jointed, but forming a fairly solid mass, suitable for the foundations of the dam. The stream in the canyon runs on bed rock.

The drainage area tributary to this site is estimated from the map at about 90 square miles. The waters from the reservoir might be conveyed a distance of 10 miles down the valley to Fort Sill and thence over the prairie lands in the vicinity of Lawton. The height of the dam site above Lawton is 200 feet, and the water would be available upon the highest prairies of the neighborhood.

The value of this reservoir site is limited by the small area tributary to it. Medicine Bluff has the reputation of being a comparatively constant stream for the region; but from field observation, without measurement, it would appear probable that the greater part of its flow throughout the year could be stored without utilizing the entire capacity of the reservoir site.

The waters from Medicine Bluff Creek flow largely from granite slopes and so far as they are derived from other rocks are not contaminated by gypsum or alkali.

LOWER NARROWS OF OTTER CREEK.[b]

In sec. 9, T. 3 N., R. 17 W., several branches of Otter Creek assemble in a usually flat valley, and the combined stream enters a canyon about 200 feet wide and approximately 100 feet deep, with nearly vertical walls. The conditions are the same as those already described on Medicine Bluff, except that the valley above the canyon is much broader and shallower and the canyon is narrower. It is estimated from the map that the drainage area of Otter Creek tributary to this reservoir site is about 125 square miles. Surveys have been made by the Otter Creek Irrigation Company on the basis of a dam 60 feet in height, constructed to throw the water over the lowest point into the divide on the southeast, and according to Mr. Mark Roberts, the originator of the plan, the area included within the contour at a level of the top of the 60-foot dam is 6,000 acres, and the average depth of water in the reservoir would be about 20 feet. Aneroid readings appear to agree fairly well with Mr.

[a] First Ann. Rept. Recl. Service, U. S. Geol. Survey, 1903, p. 267.
[b] Op. cit., p. 268.

Roberts's statements of the position of the outline of the reservoir, at least along the route by which it was crossed.

The area to be irrigated by the water which may be thus stored lies south of Mountain Park, on the lower course of Otter Creek and along Red River. The area of agricultural lands available is probably more than can be supplied by the drainage basin, which it is proposed to utilize, and the capacity of the reservoir also is probably sufficient to hold the water that can be stored from that basin.

The waters of Otter Creek flow in part from hills of igneous rock, but in greater part from areas of red beds. They do not, however, contain any notable quantity of gypsum or alkali.

QUARTZ MOUNTAIN SITE.[a]

North Fork of Red River is joined in T. 5 N., R. 20 W., by a very considerable stream known as "Elm Fork," the waters of which contain a large amount of gypsum and probably of other salts. Any irrigation plan contemplating the use of the waters of North Fork of Red River should exclude those of Elm Fork on this account. Above its junction with Elm Fork, North Fork of Red River flows from a valley in the red beds across a small area of granite in the east end of Quartz Mountain. The narrowest point of the short canyon which is thus formed in the eastern part of sec. 22, T. 5 N., R. 20 W., and the wider valley above the canyon occupies sections 14 and 15. The canyon has a minimum width at water level of 500 feet. The depth to granite in the bottom land is indeterminate. Fence posts are sunk in red and green clays of the red beds just below the narrowest part, and it may be inferred that the granite is not near the surface, even at the dam site; but the shales and sandstones of the red beds would probably afford an equally substantial foundation. It was stated that even when the river bed is otherwise dry there is always a pool of water next to the granite at the dam site, and this would seem to indicate that the underflow was brought to the surface by ledges of rock. About 200 yards west of the canyon there is a depression in the granite ridge 80 feet above the river, and this would limit the depth of the reservoir unless a supplementary dam were placed in that gap. The gap is narrow and could be easily controlled by closing it with the dam or by utilizing it as waste way. A dam 80 feet high would back the water up the valley of Red River for many miles, and would constitute a reservoir of very large proportions. The foundations and walls at the dam site appear to be adequate for any such construction.

The drainage basin of Red River tributary to this site is roughly estimated at 3,000 square miles. The quality of water, even in the autumn season, is good, although slightly saline to the taste. The water from this site could most easily be conducted across Elm Fork and southwestward into Greer County. The Otter Creek Irrigation Company proposes, however, to divert at least the flood waters to a canal extending east from the above-described dam site to Tepee Creek, and thence across to Elk Creek, by a deep cut in the divide, to the basin of Otter Creek. Surveys for this purpose were contemplated late in October.[b]

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[a] Op. cit., p. 268.

[b] Since the above was written Mr. Gerard H. Matthes and other engineers of the Reclamation Service have pursued extensive investigations on the Wichita Mountain reservoir sites. The results of their work will be found in Second Ann. Rept. Recl. Service, U. S. Geol. Survey, 1904, pp. 412, 423.

Pl. XVIII, A, shows the location of the dam site at Quartz Mountain.

CIMARRON RIVER SITE.

On the Cimarron River, in northeastern Beaver County, Mr. W. G. Russell describes a reservoir site as follows:[a]

A suggested opportunity for construction of storage works has been pointed out in sec. 32, T. 5 N., R. 6 E. of the Cimarron meridian. The river at this point passes a bluff 30 feet or more high. To the south the overflowed bottom is about one-half mile wide, and to the north the ground rises gradually for a quarter of a mile before gaining the height of the south bluff. A dam 30 feet above the river would measure about one-half mile in length, and one-fourth mile additional would be required to complete it on the north slope. The bottom lands increase in width above the dam site, and the fall of the river being approximately 8 feet to the mile, it is estimated that a reservoir could be created about 3.5 miles long by 1 mile wide, having a capacity in round numbers of 35,000 acre-feet. A survey has not been made, but these figures are given from inspection of the ground. It is believed that the flow of the Cimarron River is sufficient to fill this reservoir. Below it are lands situated on both sides of the river. It is claimed that there is an impervious clay lying only a few feet below the bed of the river upon which a dam could be formed. A structure placed at this point must be built presumably of earth, as there is little rock in sight. On the tops of the bluffs, about 300 feet above the river, are fragments of a porous limestone, which may be used in concrete or for revetment on the slopes.

The construction of a dam across the Cimarron, in Beaver County, is a difficult undertaking, and one which must be given careful consideration. Little can be known without expensive surveys and borings to ascertain the character of the foundations and the proper material to be used in the structure.

UTILIZATION OF STORM WATERS.

In addition to the sites mentioned, all of which are located on rivers, there are in western Oklahoma hundreds of places where small dams might be thrown across small watercourses, draws, or arroyos, forming a reservoir for the storing of storm waters. In many instances, such reservoirs could be so located as to irrigate many acres of fertile land now too dry to yield satisfactory crops.

Some of the difficulties are, first, relatively small amounts of rainfall; second, the great evaporation, and third, sandy character of the soil. The rainfall of Beaver County varies from 20 inches in the eastern part to less than 10 inches near the New Mexico line. The greater part of this precipitation usually falls during a few heavy downpours, amounting often to cloud-bursts, while for months at a times almost no rain will fall. A difficulty, of course, is that after a heavy rain, any but the most strongly constructed dams will be washed out.

There are few data available as to the amount of evaporation in the

[a] Op. cit., p. 271.

region under discussion, but it amounts to at least 6 feet per year in the western portion of the Territory. As stated by Johnson and others, there are large areas where there is practically no run-off, the drainage flowing down shallow draws into playa lakes. Areas of many square miles are as flat and level as a floor, and the water that falls remains on the surface of the ground until it is evaporated.

In a region of this kind, with high summer temperature and almost constant wind, it would be expected that a large proportion of water collected in reservoirs would soon be evaporated. Lakes on the Plains usually go dry during the summer, and the same conditions obtain in artificial reservoirs, except that these can be made of sufficient depth to provide a surplus of water beyond the evaporation.

Much of the soil in this region is sandy, particularly along the streams where reservoirs must usually be constructed. In the sand-hill districts there is practically no run-off; the water is either evaporated or soaks into the soil, and it goes without saying that it is useless to locate a reservoir in such a locality.

Notwithstanding the objections cited in the preceding paragraphs, however, there are plenty of places in central and western Oklahoma where a reservoir a few acres in extent might be profitably constructed which would afford useful water storage. The writer does not venture an opinion as to whether such projects would be profitable. The problem is one, however, that should be carefully investigated.

IRRIGATION FROM SPRINGS.

At best, irrigation from springs can be but local, on account of the relatively small amount of water supplied from even the strongest. Of the various classes of springs in Oklahoma, the water from red beds and Tertiary springs only is used for purposes of irrigation; in by far the greater number of instances a Tertiary spring is so used. As has been stated in another part of this report, the supply from these springs is practically inexhaustible, the amount from a single one often approximating several second-feet. The quality of the water leaves little to be desired, being usually pure, sweet, and free from mineral salts. The chief difficulties in the way of irrigation from these springs are those of location. Tertiary springs issue almost invaribly along the line of unconformity between the red beds below and the Tertiary above, as shown in figs. 29 and 30, and usually in a canyon or along a bluff where the country below is so rough and broken that in most cases the water can not be utilized. In a number of instances, however, the water from one of these springs is led out over a garden or orchard. The table given herewith (p. 140) sets forth the location of areas irrigated from springs so far as ascertained by the writer.

Water from Tertiary springs is utilized in another way, namely, as a source of city supply. At Alva the water from Elm Spring, 3 miles away, is carried in a pipe by gravity to the north part of the city, and then forced by a pump into the water mains and carried to all sections of the city. Old Fort Supply obtains its water from a Tertiary spring 3 miles away across Beaver Creek, the water being carried in a 6-inch main. Woodward, Grand, Beaver, and other county seats in the western part of the Territory are supplied either from Tertiary wells or Tertiary springs.

Irrigation from springs in Oklahoma.

Name of owner.	Township.	Range.	Section.	Irrigation section.	Kind.	Acres.	Crops irrigated.
John Cornvine	25	1 W.	13	SW.	Tertiary		
W. E. Miller	24	16 W.	2	NE.	do		
Jacob Eckart	22	21 W.	4	NE.	do	3	Garden.
A. L. McPherson	23	21 W.	14		do		
S. A. Pollock	23	21 W.	4		do	5	
J. E. Fitzlin	28	14 W.	8	NE.	do	10	Garden and orchard.
A. C. Grimes	28	14 W.	35	SW.	do	3	Garden.
L. F. La Brue	27	9 W.	9	NW.	do	12	Produce and orchard.
Wm. Crow	27	8 W.	20	SW.	do	1	Garden.
M. L. Bodenheimer	25	10 W.	9	SE.	Red bed	3	Orchard.
Levi Manning	22	10 W.	15	NE.	Tertiary	12	Garden and orchard.
F. M. Matthews	27	9 W.	33	NE.	do	9	
M. L. Guffey	27	9 W.	4	SW.	do		
Adam Walck, sr	17	4 W.	6	NE.	Red bed		
C. N. Jett	25	9 W.	2	NW.	do	6	Orchard.
Do	25	10 W.	36	NE.	do	12	Garden.

IRRIGATION FROM WELLS.

In a great part of western Oklahoma there is sufficient underground water, if it were brought to the surface, to irrigate considerable areas. The difficulty here is that no cheap method has yet been devised whereby sufficient underground water may be elevated from considerable depths to be of practicable importance. Windmills seem to furnish the simplest solution of the problem, and considerable literature has already accumulated on the subject.[a] Pl. XV gives types of Oklahoma windmills.

In western Oklahoma a great part of the water lies at depths of 100

[a] For a discussion of the relation of windmills to water supply the reader is referred to the following numbers of the Water-Supply and Irrigation Papers of the U. S. Geological Survey:

No. 1. Pumping water for irrigation, Herbert M. Wilson, 1896.
No. 8. Windmills for irrigation, C. E. Murphy, 1897.
No. 14. New tests of certain pumps and water lifts used in irrigation, O. P. Hood, 1898.
No. 20. Experiments with windmills, T. O. Perry, 1899.
No. 29. Wells and windmills in Nebraska, E. H. Barbour, 1899.
Nos. 41 and 42. The windmill, its efficiency and economic use, E. C. Murphy, 1901.

to 400 feet, and windmills have so far proved inadequate to the task of lifting sufficient quantities of water for irrigation purposes. Farms and ranches are supplied by windmills, and in certain parts of Oklahoma to-day lone windmills are the only signs of civilization, but in most cases all efforts to secure a greater supply of water than is necessary for stock and domestic purposes has proved a failure. The problem is one that deserves attention and which may in time yield practical results.

CLIMATE.

Eastern Oklahoma lies in the humid, western Oklahoma in the semiarid, and extreme western Beaver County in the arid belt of the

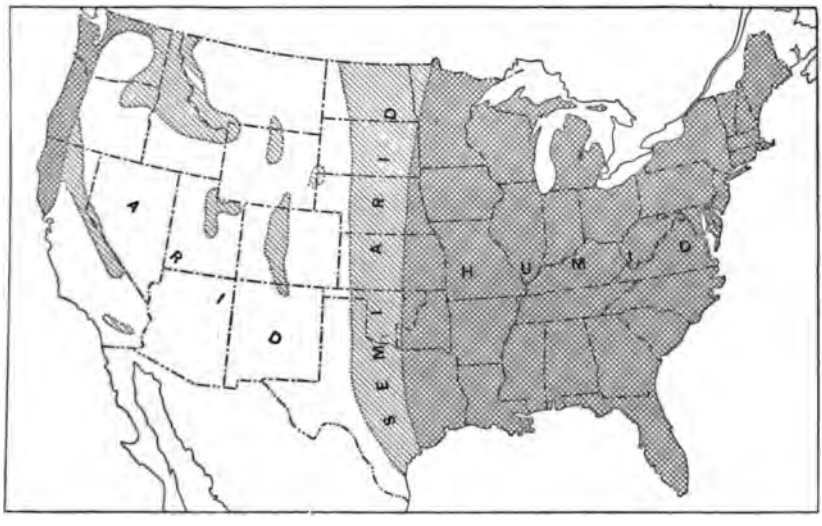

FIG. 31.—Map showing the arid, semiarid, and humid regions of the United States.

United States, as these belts are usually demarked (see fig. 31). In the Osage Nation and the eastern tier of counties the annual precipitation for the last ten years has averaged about 35 inches. In central Oklahoma during the same time the average has been 30 inches, along the western line, exclusive of Beaver County, 25 inches, and in the western part of this county the annual rainfall has not exceeded 15 inches (see fig. 32).

In the eastern part of the Territory the rainfall is not only more abundant, but it is also more evenly distributed. As a general thing rain falls during every month, but on the average there are more than 175 clear days in the year, while days with 0.1 inch precipitation will not average more than 70 each year. On the high plains the precipitation is neither regular nor abundant. For months at a time there may be practically no rainfall, when, again, during a heavy

storm, often amounting to a cloud-burst, a level plain will be covered with several inches of water.

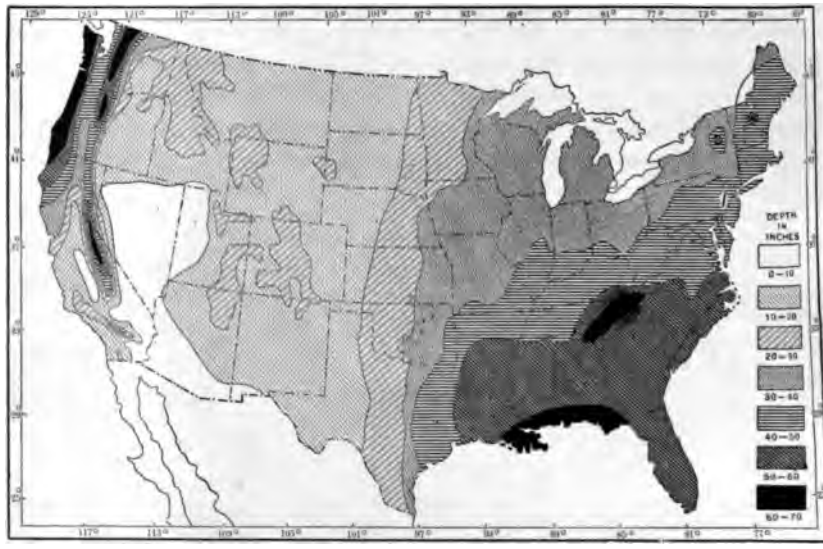

FIG. 32.—Map showing the mean annual rainfall of the United States.

The mean annual temperature for ten years has been 59°, varying from 55° in Beaver County to 62° in Comanche. The winters are mild and the heat of the summers tempered by almost constant breezes.

WATER ANALYSES.

METHOD.

The calcium oxide, magnesium oxide, sulphuric anhydride, chlorine, and solid residue are determined in the usual way, using Cheever and Smith, Sutton, Cairns, and Mason as guides. The carbon dioxide is not estimated, but is calculated by differences.

In general, in this report, the metals in their combination with the acids are taken in the following order: Calcium, magnesium, sodium.

In their combination with the metals the acids are taken in order as follows: Sulphuric acid, hydrochloric acid, carbonic acid.

These combinations are only hypothetical, yet they can not fail to give a better idea of the constituents of the water, and it is merely for this purpose that such combinations have been made.

DEFINITION OF TERMS.

That the general reader may more readily understand the analyses given below, the following definitions and explanations of terms are given:

Grains per gallon.—The number of grains per United States gallon are determined from the parts per million on the basis that " 1 United

States gallon of pure water at 60° F., weighed in air at 60° F. at atmospheric pressure of 30 inches of mercury, weighs 58,334.946 grams."[a]

Common names.—Calcium sulphate is gypsum, and in its dried form is commonly known as plaster of Paris; calcium carbonate is limestone; magnesium sulphate is Epsom salt; sodium sulphate is Glauber's salt; sodium chloride is common salt; sodium bicarbonate is common baking soda. All the remaining salts occurring in the analyses have no common names.

COMPARISON OF RED-BEDS WELLS.

To show the great variations in the supply and quality of waters from the red beds, even in the same locality, eight wells within a radius of two blocks in the city of Norman, Okla., have been taken as an example.

Comparative table showing variation of red-beds waters.

[Parts per million.]

Sample No.	How put down.	Kind of rock.	Total depth.	Depth to water.	Depth of water	Variation of water depth at different times of year.	Amount of water.
			Feet.	*Feet.*	*Feet.*		
7	Dug	Red beds	28	12	16	None	Not easily lowered.
8	do	do	30	25	5	Very slight	Do.
9	Drilled	do	50	14	36	None	Do.
10	do	do	20	16	4	Very slight	Quite easily lowered.
11	Dug	do	23	14½	8½	Considerable	Not easily lowered.
12	do	do	25	21	4	do	Do.
13	do	do	23	21	2	do	Quite easily lowered.
14	do	do	24	21	3	do	Do.

Sample No.	Calcium oxide.	Magnesium oxide.	Sulphuric anhydride.	Chlorine.	Total residue.	Normal hardness.	Carbon dioxide.
7	115.0	9.0	271.0	160.0	945.0	58.5	146.0
8	122.0	60.0	256.0	60.5	621.0	53.3	121.8
9	242.0	220.0	1,129.0	1,185.0	4,365.0	1.3	147.0
10	152.0	139.0	709.0	750.0	2,980.0	3.9	None.
11	53.0	43.0	68.0	33.0	572.0	9.6	124.0
12	174.0	96.0	236.0	104.0	1,099.0	14.3	146.0
13	137.0	96.0	58.0	89.5	856.0	11.7	170.0
14	137.0	63.0	50.0	54.5	641.0	14.3	130.0

[a] Mason's Examination of Water, 2d ed., 1901, p. 93.

The wells selected are Nos. 7 to 14, inclusive, in the general report of analyses.

Sample No. 7 is a dug well, 28 feet in depth. In this the depth of water is 16 feet. No. 8, less than a block from No. 7, is 30 feet in depth and has but 5 feet of water. The supply of water in both is practically constant the year around and is not easily lowered by excessive use. In calcium oxide, sulphuric anhydride, normal hardness, and carbon dioxide Nos. 7 and 8 differ but slightly. However, in magnesium oxide No. 7 is very low and No. 8 is comparatively high, while No. 7 greatly exceeds No. 8 in chlorine and total solid residue. These differences are remarkable because the geologic and sanitary surroundings of the wells are apparently the same.

Nos. 10 and 11 also make an interesting comparison. No. 10 is 20 feet deep, varies but slightly in water depth at different times of the year and is easily lowered by excessive use. No. 11, distant from No. 10 by but a little more than the width of a street, is 23 feet deep, contains 8½ feet of water, varies considerably in water depth at different times of the year, and is not easily lowered by excessive use. With a difference of but 3 feet in depth, and so close together, the difference in the amount of water constituents is worthy of notice. In No. 10 the calcium oxide, magnesium oxide, and solid residue are about five times that of No. 11, while the sulphuric anhydride is about ten times and the chlorine twenty-five times as much. The normal hardness of each is small, but that of No. 11 is more than twice that of No. 10, which has no carbon dioxide as carbonates, while No. 11 has a fairly large amount. It might be noted here that No. 11 runs lower in nearly all the tests than any other water taken for comparison.

In the same block with No. 11 are wells Nos. 12, 13, and 14, occurring in the order given. The width of the two lots separates wells No. 11 and No. 12. The depths of these wells are practically the same, yet in No. 12 the solid constituents greatly exceed in amount those of No. 11, running especially high, comparatively, in calcium oxide, sulphuric anhydride, chlorine, and solid residue. Wells Nos. 12 and 13 are separated by about the width of one lot and differ by but 2 feet in depth. In No. 13 the calcium oxide, chlorine, solid residue, and normal hardness are but slightly less than in No. 12; the magnesium oxide is the same in both; the carbon dioxide in No. 13 is higher than in No. 12, but the most noticeable difference is that of the sulphuric anhydride, which in No. 13 is but about one-fourth of that in No. 12. No. 14 differs but little from Nos. 11 and 13.

All of the wells so far compared have been between 20 and 30 feet in depth. It may therefore be of interest to include one deeper well. For this comparison No. 9 will answer the purpose. Both No. 9 and

). 10 are on the same lot, about 40 feet apart. No. 9 is a drilled ·ll 50 feet in depth and contains 36 feet of water. It might be well note in this connection that good water was struck at 14 feet and a depth of 40 feet salt water was encountered. This lower stream water has rendered the well altogether unsuitable for drinking rposes. In this water the calcium and magnesium oxides are con- lerably higher than in any other of the waters taken for compari- ı, while the sulphuric anhydride, chlorine, and solid residue are ·essively high.

All other deep-well waters from this section of the country which ve been analyzed have, like No. 9, run exceedingly high in sul- uric anhydride, chlorine, and solid residue. These deep-well ıters also vary greatly, although perhaps not so noticeably as the ıters from the shallower wells.

The wells used in the above comparison may be considered as pical of all the wells having their origin in the red beds. For gen- al domestic purposes the shallow wells are the more satisfactory, al- ough few of these contain water which can be classed as really ıod. In short, the red beds make a poor and unreliable source of ıter supply.

Analyses of Oklahoma well waters—Continued.

Number.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents.									
								Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
	Kingfisher County:																
44	Omega	10.0	3.4	16.2	39.4	114.2	8.3	.....	.....	17.8	8.8	.....	1.0	18.3	64.9	2.1	.....
45	Kingfisher	9.0	5.1	11.6	10.2	68.6	8.98	.....	.....	16.2	10.3	.....	3.6	2.4	16.3	1.0	.....
46	Kingfisher, 6 miles east and 2½ miles south	1.6	3.8	12.7	4.7	50.2	7.6	.....	.....	13.4	5.6	.....	3.6	15.9	7.7	1.3	.....
47	Downs	3.9	1.3	.8	2.3	26.3	4.4	.....	.....	6.9	.4	.....	2.6	1.1	3.5	7.7	.....
	Kiowa County:																
48	Secs. 11 and 12, T. 2 N., R. 17 W	14.1	2.97	11.7	35.2	94.6	7.7	19.9	11.6	.....	.....	7.0	.....	.....	47.1	18.8	.....
	Logan County:																
49	Guthrie, city park	67.0	18.4	116.3	590.4	1,200.0	39.2	162.9	.....	.....	20.7	18.9	.....	.....	943.0	.....	74.9
50	Guthrie, city water supply	9.5	4.9	5.8	4.7	45.3	15.8	9.9	4.9	.....	.....	.1	10.1	.....	.....	.....	20.2
51	Langston	6.1	5.1	1.98	10.5	44.3	6.3	.....	.....	10.9	2.98	6.8	2.7	.....	9.0	3.1	.....
	Noble County:																
52	Billings, sec. 14, T. 23 N., R. 3 W	5.7	3.3	50.5	67.7	238.8	.0	13.9	.....	.....	9.9	.....	.....	63.3	111.8	.....	.....
53	Billings, SE. ¼ sec. 29, T. 24 N., R. 2 W.	3.3	4.8	7.5	18.8	69.0	11.6	7.9	.....	.....	4.3	7.98	.....	.....	21.3	.....	22.1
54	Redrock	Trace.	.0	8.4	.6	28.3	5.1	.....	.....	.....	.....	.....	.....	14.8	.96	12.4	.....
55	Redrock, NE. ¼ sec. 25, T. 23 N., R. 2 E.	4.3	.0	3.7	1.2	26.5	3.3	6.2	4.9	1.3	.....	.....	.....	.....	.....	6.5	.....
56	Perry, NW. ¼ sec. 22, T. 21 N., R. 1 W.	74.6	16.4	160.0	104.5	458.2	.6	181.3	.....	.....	46.9	.....	.....	37.4	172.4	1.5	.....
	Oklahoma County:																
57	Choctaw City, lot 8, block 28	2.4	1.8	3.0	1.2	17.3	2.5	5.2	.9	.....	.....	.9	2.9	.....	.....	2.4	.....
58	Sweeney, SW. ¼ sec. 23, T. 12 N., R. 1 E.	1.6	.6	.3	1.4	9.6	1.7	.5	2.1	.95	.....	.....	1.3	.....	.....	1.4	.....
59	Oklahoma City, NE. ¼ sec. 4, T. 12 N., R. 4 W	25.6	6.8	53.8	1.8	132.8	6.2	62.1	.....	.....	20.3	.....	.....	7.1	2.9	14.9	.....

60	Oklahoma City, sec. 9, T. 12 N., R. 4 W.	4.8	1.5	1.9	2.3	21.9	3.1	3.2	3.6	2.9	.....	.....	3.2	.....	.....	.....	.....
61	Do.	6.5	3.7	8.2	2.5	38.2	6.5	13.9	1.6	.....	.....	1.98	5.8	.....	.....	.4	.....
62	Oklahoma City, sec. 33, T. 12 N., R. 3 W.	7.9	.4	1.2	.4	21.9	5.8	1.98	.5	17.2	.....	.....	.9	.....	.....	7.3	.....
63	Do.	8.1	3.97	6.4	9.9	44.7	6.0	9.8	7.3	.....	.....	7.1	2.0	.....	.....	11.9	.....
	Pawnee County.																
64	Blackburn, sec. 1, T. 21 N., R. 6 E.	6.2	3.0	4.6	.7	21.4	5.7	7.9	1.1	4.4	.....	.....	6.8	.....	.....	1.1	.....
65	Blackburn, NW. ¼ sec. 30, T. 22 N., R. 7 E.	4.96	2.9	3.5	1.2	21.6	5.2	5.95	1.95	2.8	.....	.....	6.1	.....	.....	1.9	.....
66	Blackburn, sec. 10, T. 22 N., R. 7 E.	1.6	1.1	3.8	56.6	120.7	1.2	3.96	.....	.....	2.2	.6	.....	.....	93.3	2.8	.....
67	Pawnee, SE. ¼ sec. 36, R. 4 E.	20.7	15.8	63.5	9.1	170.4	9.3	49.5	.....	.....	47.2	.....	.....	6.3	22.0	17.7	.....
68	Jennings, 1¼ miles west	3.6	1.3	1.6	1.2	29.5	2.6	2.8	1.9	2.6	.....	.....	2.8	.....	.....	.....	.....
69	Valley, NE. ¼ sec. 14, T. 21 N., R. 6 E.	8.6	2.8	8.2	60.9	135.6	6.0	13.9	5.7	.....	.....	6.6	.....	.....	144.6	14.5	.....
	Payne County:																
70	Cushing, NW. ¼ sec. 5, T. 16 N., R. 5 E.	6.4	.0	13.7	4.1	28.0	.8	11.5	.....	.....	.....	.....	.....	8.9	6.7	1.8	.....
71	Stillwater, 1 mile north	2.7	1.1	.5	1.5	26.3	2.9	.....	.....	4.8	.7	.....	1.5	.....	2.4	12.1	.....
72	Perkins, NE. ¼ sec. 14, T. 17 N., R. 2 E.	9.6	8.5	6.7	31.5	85.5	6.2	11.5	9.7	.....	.....	19.96	.....	.....	17.3	.....	21.8
73	Stillwater	3.4	.9	.2	.7	11.9	3.2	.4	1.1	4.8	.....	.....	1.95	.....	.....	.2	.....
74	Stillwater, 11 miles southwest	2.2	.9	.0	1.2	10.3	2.7	.....	1.9	2.3	.....	.....	1.95	.....	.....	1.7	.....
75	Stillwater, NW. ¼ sec. 8, T. 20 N., R. 2 E.	6.3	3.4	4.6	2.5	33.1	5.4	7.7	3.8	2.1	.....	.....	7.2	.....	.....	1.7	.....
	Pottawatomie County:																
76	Tecumseh, lot 12, block 33	3.3	.0	2.6	.7	8.5	1.5	4.4	1.1	1.6	.....	.....	.....	.....	.....	1.7	.....
77	Pink, NW. ¼ sec. 17, T. 9 N., R. 2 E.	4.2	1.0	8.2	.9	15.1	.6	10.2	.....	.....	3.0	.....	.....	.3	1.5	1.6	.....
78	Tecumseh, NW. ¼ sec. 18, T. 8 N., R. 4 E.	.2	.6	7.5	.8	19.5	1.1	.3	.....	.....	1.6	.....	.....	10.8	1.3	2.5	.....
	Woods County:																
79	Alva, lots 13 and 14, block 16	42.9	28.8	118.7	4.5	278.6	40.4	104.3	.....	.....	82.2	.....	.....	6.8	7.4	.....	77.2
80	Alva, lot 1, block 1, Ament's addition	43.9	22.1	115.2	2.2	250.8	31.8	106.7	.....	.....	68.9	.....	.....	10.7	3.6	.....	60.8
81	Ringwood	8.1	3.1	3.1	3.7	23.9	6.3	5.2	5.8	5.5	.....	.....	6.6	.....	.....	.....	.9
82	Cleo, 9 miles east and 6½ miles north	6.3	1.2	2.9	8.2	34.5	5.7	.....	.....	11.3	1.8	.....	1.3	2.6	13.5	1.5	.....
83	Cleo, town well	7.6	.8	.5	3.8	21.6	5.0	.9	1.9	11.4	.....	1.9	.....	.....	1.8	.8	.....
84	Leslie	7.3	5.1	11.1	7.3	53.1	6.3	.....	.....	13.0	13.7	.....	1.1	3.5	12.0	1.3	.....
	Woodward County:																
85	Woodward	25.6	3.7	28.5	18.9	98.4	5.8	58.4	11.1	.....	.....	6.4	.....	.....	12.4	13.9	.....

Analyses of Oklahoma stream waters.

[Grains per United States gallon.]

Number.	Stream.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents.									
									Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
86	Salt Fork, above Salt Plains.	Alva	22.2	5.1	35.7	6.5	95.3	2.1	53.9	.....	.....	5.9	5.4	.....	.....	4.8	5.1	.....
87	Salt Fork, below Salt Plains.	Pond Creek, ½ mile east	7.9	3.2	24.96	178.5	347.8	2.7	19.3	.....	.....	8.5	.....	.....	12.9	294.5	6.6	.....
88		At ford south of Ponca School.	17.4	3.8	22.3	286.7	516.2	.6	38.15	.....	1.5	1.1	8.2	.....	.....	463.3	.5	.....
89	Tributaries of Salt Fork.	Chikaskia River, west of Ponca City.	4.8	1.8	4.0	1.8	20.5	3.7	.4	.....	8.3	5.3	.....	.....	.5	2.9	.4	.....
90		Deer Creek, west of Tonkawa.	6.7	2.7	5.3	9.6	33.7	.9	8.9	3.7	1.98	.....	6.4	.....	.....	4.3	1.3	.....
91	Cimarron River, above Woodward County Salt Plains.	At head of Col. C. D. Perry's ditch.	7.0	3.4	10.1	43.8	103.6	7.7	17.0	.....	.....	.2	5.8	.....	.....	65.9	.....	14.7
92		Kenton	7.6	4.3	36.5	3.97	97.7	15.9	18.4	.....	.....	12.9	.....	.....	30.3	6.5	.....	29.6
93	Cimarron River, below Woodward County Salt Plains.	Waynoka, 4 miles southwest.	8.9	1.1	12.4	232.8	420.6	4.7	21.0	.4	.....	.....	1.8	.....	.....	371.6	11.2	.....
94		Kingfisher, 8 miles north	24.0	9.7	34.2	355.9	664.5	2.6	68.2	.1	.....	.....	22.9	.....	.....	559.1	6.2	.....
95		Langston, 3 miles east	14.3	5.6	21.7	205.3	385.6	3.5	23.9	.....	7.9	10.7	4.8	.....	.....	332.8	.5	.....
96		Guthrie, 2 miles north	18.1	6.7	13.8	245.7	463.1	3.0	23.4	16.7	.....	.....	11.7	.....	.....	375.1	6.5	.....
97		Perkins, 2½ miles southeast	14.23	4.9	17.7	216.9	397.3	3.9	30.1	3.6	.....	.....	13.5	.....	.....	336.8	9.3	.....
98		Perkins, at crossing south of town.	8.3	1.2	7.5	34.7	74.7	1.9	12.7	6.2	.....	.....	2.7	.....	.....	47.3	4.5	.....
99		Cleo, at ford south of town	16.4	2.7	24.4	236.3	435.9	2.3	32.9	.....	5.1	7.6	.4	.....	.....	389.3	.6	.....
100	Tributaries of Cimarron	Cottonwood Creek, north of Guthrie.	12.4	5.1	17.4	3.4	61.6	14.3	29.6	.5	.....	.....	4.2	6.9	.....	.....	.....	20.4

No.																		
102	Tributaries of Cimarron.	Boomer Creek, ¼ mile east of Stillwater.	7.9	2.97	3.5	1.1	35.6	7.4	5.95	1.6	8.3	.....	.....	7.1	.....	.....	.....	.....
103		Council Creek, 3½ miles northwest of Ingalls.	1.9	1.8	.2	.7	13.9	3.5	.3	1.1	2.2	.....	.....	3.7	.....	.....	1.5	.....
104		Little Stillwater Creek, 6 miles east of Stillwater.	3.9	1.6	.0	.8	23.2	6.1	.....	1.2	5.9	.....	.....	3.3	.....	.....	5.8	.....
105		Salt Creek, 10 miles northeast of Ingalls.	3.2	2.3	0.0	0.8	15.1	5.3	.....	1.2	4.6	.....	.....	4.8	.....	.....	1.9	.....
106		Wild Horse Creek, 11 miles southwest of Stillwater.	3.97	3.6	0.0	1.8	32.2	6.9	.....	2.8	4.5	.....	.....	7.5	.....	.....	0.97	.....
107		Stillwater Creek, ¼ mile south of Stillwater.	1.5	0.9	1.1	0.2	10.0	1.8	1.8	0.4	1.0	.....	.....	1.8	.....	.....	0.95	.....
108		Dog Creek, Waynoka	7.2	3.6	7.5	2.1	35.9	5.5	12.8	3.3	0.5	.....	.....	7.6	.....	.....	3.7	.....
109		Salt Creek, ¼ mile below Salt Spring, Ferguson.	198.5	87.3	192.3	7,930.0	(a)	(a)	327.0	126.3	.....	.....	153.4	.....	.....	12,824.2	.....	(a)
110		Cottonwood Creek, ¼ mile north of Guthrie.	3.1	1.2	3.5	2.5	17.4	2.7	5.95	1.3	.....	.....	2.0	.....	.....	0.5	6.5	.....
111	Arkansas River and tributaries.	Ponca City, 2 miles east	6.5	0.4	3.2	7.6	29.8	3.9	0.8	.....	8.8	1.1	.....	.....	3.5	12.5	0.3	.....
112		Black Bear Creek, 2 miles northwest of Stillwater.	6.5	3.0	2.1	3.2	34.8	6.4	.....	.....	11.6	3.2	2.5	2.6	.....	2.2	8.2	.....
113		Red Rock Creek, at Otoe School.	3.5	0.9	1.2	1.5	14.6	2.98	1.3	.....	5.4	0.6	1.6	.....	.....	0.4	1.3	.....
114		Black Bear Creek, north of Stillwater.	6.1	1.6	0.6	1.4	29.1	5.5	1.1	2.2	8.1	.....	.....	3.4	.....	.....	0.5	.....
115	North Canadian and tributaries.	Beaver Creek, sec. 9, T. 4 N., R. 22 E.	7.2	5.6	13.3	38.7	99.3	7.3	18.3	.....	.....	4.4	7.2	.....	.....	56.1	.....	13.0
116		Paladuro Creek, NE. ¼ sec. 23, T. 1, R. 18.	6.5	1.0	8.3	10.4	42.0	5.8	14.1	1.5	.....	.....	1.7	.....	.....	13.7	.....	11.0
117		Cold Water Creek, Hardesty, Okla.	7.5	1.9	12.6	8.6	50.3	4.9	18.1	.....	.....	2.9	1.7	.....	.....	12.4	.....	9.4
118		North Canadian, at Cantonment.	7.5	2.3	9.6	19.5	65.2	4.1	5.7	.....	9.3	7.0	.....	.....	2.8	32.3	1.5	.....
119		North Canadian, 4 miles northwest of Watonga.	5.5	3.9	10.3	19.5	67.7	2.8	4.8	.....	6.4	11.2	0.4	.....	.....	31.7	1.0	.....
120		North Canadian, 2 miles north of El Reno.	6.9	4.6	11.8	14.0	58.0	3.3	16.9	.....	.....	2.8	6.3	.....	.....	16.3	8.0	.....
121		North Canadian, at Sweeney	6.2	3.2	3.9	6.3	36.3	5.8	6.6	6.8	.....	.....	3.3	2.3	.....	.....	10.98	.....
122		Branch of Deer Creek, NE. ¼ sec. 4, T. 12 N., R. 4 W.	16.5	4.3	30.2	1.4	83.4	5.5	39.95	.....	.....	9.97	1.9	0.4	.....	.....	12.7	.....

(a) Not determined.

Analyses of Oklahoma stream waters—Continued.

Number.	Stream.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents.									
									Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
123	North Canadian and tributaries.	North Canadian, 1 mile south of Oklahoma City.	10.2	3.8	9.7	10.5	48.2	4.8	16.5	6.6	.....	.....	6.7	.....	.....	3.1	11.7	.....
124		North Canadian, at Shawnee	4.1	0.0	4.1	(a)	(a)	4.4	7.0	.....	2.1	.....	.....	.....	.....	.....	.....	6.6
125		Clear Creek, S. ½ sec. 24, T. 25 N., R. 25 W.	6.7	3.4	3.1	3.9	23.8	6.5	5.2	6.1	2.5	.....	.....	7.2	.....	.....	.....	2.7
126		Boggy Creek, at Whitehead.	6.7	0.5	4.0	1.7	21.7	6.0	6.8	2.7	4.6	.....	.....	1.1	.....	.....	.....	6.6
127		Wolf Creek, 2 miles north of Whitehead.	6.5	1.3	4.1	5.7	27.8	3.2	6.9	7.3	.....	.....	1.4	1.6	.....	.....	.....	4.6
128		Beaver Creek, at mouth of Kiowa Creek.	7.6	0.8	13.6	28.9	82.7	6.4	18.7	.....	.....	2.4	.....	.....	1.7	47.6	.....	12.2
129		North Canadian, at Woodward.	6.3	2.9	9.5	14.9	53.0	3.7	15.3	.....	.....	0.7	4.8	.....	.....	19.4	9.0	.....
130	South Canadian River.	South Canadian, 11 miles south of El Reno.	17.5	5.3	33.3	4.9	76.0	2.0	42.4	.....	.....	12.4	1.9	.....	.....	6.0	4.9	.....
131		South Canadian, at 100th meridian.	9.0	3.0	14.5	11.0	64.3	12.0	21.97	.....	.....	2.4	5.3	.....	.....	11.7	.....	22.96
132		South Canadian, 3½ miles E., ½ mile S. of Taloga.	4.8	1.98	7.6	4.4	31.0	2.9	4.4	.....	6.5	5.95	.....	.....	1.98	7.2	0.5	.....
133		South Canadian, at Noble ..	6.3	2.8	9.2	4.6	37.7	4.2	15.3	.....	.....	0.3	4.7	.....	.....	2.4	10.1	.....
134	Wichita Mountain streams.	Medicine Bluff Creek, 2 miles above Fort Sill.	5.0	1.1	2.5	1.2	13.5	3.9	4.3	1.9	4.1	.....	.....	3.2	.....	.....	.....	.....
135		Cache Creek, SE. ¼ sec. 29, T. 2 N., R. 11 W.	6.9	1.6	5.1	1.5	24.6	6.8	8.6	2.4	3.9	.....	.....	2.3	.....	.....	.....	6.4

a Not determined.

Analyses of Oklahoma spring waters.

[Grains per United States gallon.]

No.	Kind of spring.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents.									
									Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
136	Terrace	Lawton, ½ mile south, on Rock Island right of way.	4.7	0.7	3.7	0.8	25.4	9.1	6.3	1.3	2.4	.....	.....	1.5	.....	.....	.....	13.9
137	Limestone	Lawton, Dunbar Springs, NW. ¼ sec. 16, T. 2 N., R. 12 W.	6.5	1.4	5.0	1.6	18.2	3.5	8.5	2.5	3.1	.....	.....	2.9	.....	.....	.....	1.2
138	Limestone	Newkirk, NE. ¼ sec. 15, T. 28 N., R. 3 E.	7.1	2.3	1.2	1.3	20.2	7.4	1.98	2.1	9.3	.....	.....	4.9	.....	.....	1.9	.....
139	Limestone	Uncas, SE. ¼ sec. 13, T. 27 N., R. 4 E.	7.8	2.2	.7	.5	23.0	7.8	1.2	.8	12.2	.....	.....	4.5	.....	.....	.2	.....
140	Sandstone	Baker, SE. ¼ sec. 14, T. 16 N., R. 5 E.	3.2	1.4	.4	.6	11.7	3.7	.7	.9	4.3	.....	.....	2.9	.....	.....	.8	.....
141	Sandstone	Guthrie, lots 11 and 12, block 11	13.4	6.6	4.4	12.9	66.7	14.9	7.4	20.1	.3	.....	.....	12.6	.....	.....	19.7	.....
142	Sandstone	Pawnee, NE. ¼ sec. 12, T. 21 N., R. 5 E.	6.4	2.3	1.0	.9	19.7	7.1	1.7	1.4	8.9	.....	.....	4.9	.....	.....	1.5	.....
143	Sandstone	Whitehorse, Whitehorse Springs, NW. ¼ sec. 21, T. 27 N., R. 16 W.	6.1	3.3	4.1	1.2	26.6	8.9	7.1	1.8	4.0	.....	.....	6.96	.....	.....	.....	6.8
144	Sandstone	Whitehorse, SE. ¼ sec. 7, T. 27 N., R. 16 W.	5.2	2.4	9.4	1.9	26.4	3.7	12.6	.....	.....	3.8	2.0	.....	.....	0.9	.....	7.0
145	Tertiary	Alva, Elm Grove Springs	3.1	1.98	.9	.5	10.9	4.1	1.6	.9	3.6	.....	.....	4.1	.....	.....	.....	.7
146	Tertiary	Ringwood	6.9	2.6	2.7	3.1	20.3	5.3	4.6	4.9	4.5	.....	.....	5.4	.....	.....	.....	.9
147	Tertiary	....do	6.1	3.1	2.3	2.9	19.6	5.6	3.8	4.5	4.1	.....	.....	6.5	.....	.....	.....	.7
148	Tertiary	....do	18.6	9.9	35.3	63.9	173.3	5.4	45.1	.....	.....	13.2	9.5	.....	.....	95.2	.....	10.2
149	Tertiary	Alva, 2 miles north	3.7	1.2	1.2	.9	14.6	3.2	2.1	1.5	3.8	.....	.....	2.4	.....	.....	.6	.....
150	Salt	Blaine County, in south canyon, head of Salt Creek.	210.8	97.8	164.3	9,065.3	(a)	(a)	279.3	189.6	.....	.....	171.9	.....	.....	14,571.7	.....	(a)
151	Salt	Ferguson, in north canyon, Salt Plain.	195.2	78.5	196.7	7,697.3	(a)	(a)	334.7	113.5	.....	.....	137.9	.....	.....	12,431.9	.....	(a)

[a] Not determined.

Analyses of Oklahoma pond waters.

[Grains per United States gallon.]

No.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents.									
								Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
	Grant County:																
152	Lamont, 1 mile east and ¼ mile north	1.2	0.2	0.0	0.3	13.5	0.4	(a)	0.5	0.9	.....	.....	.....	.....	.....	0.5	.....
153	Pond Creek, 5 miles west	.7	.3	.0	1.2	19.9	1.2	.....	.....	1.3	.....	.....	0.6	.....	1.9	6.9	.....
	Logan County:																
154	Langston, 5 miles west and 1 mile south	1.5	.2	.0	.3	7.0	1.8	.....	.....	2.6	.....	.....	.4	.....	.5	.5	.....

[a] Traces of calcium and magnesium silicates.

WELL RECORDS.

On the following pages are given descriptive notes of 10 wells from each of the 26 counties in Oklahoma. These data were obtained by a complete canvass of all available sources of information, mainly by schedules sent by mail. Returns from over 5,000 wells were received from all parts of the Territory, probably representing all classes of wells. In the selection of data presented in the table care was taken to include only those which were most typical for each general locality and which represented ordinary conditions. It is believed that these records show the typical hydrologic conditions for the Territory, although in some cases there are local conditions which may differ more or less widely from those indicated.

In several instances there has been considerable difficulty in ascertaining the geological horizon of the water-bearing stratum, and for that reason the statements given in the column headed "Geological horizon" are to be accepted only tentatively. Where the term "red beds" is used, it is to be understood in the sense of the Pennsylvanian red beds. When the well is located in the undoubted Permian, that word is used. It will be observed that in general wells in the Tertiary and the (Pennsylvanian) red beds contain soft water, while those in the Permian yield hard water, but in a few localities the conditions are exceptional in that respect.

The height of the water level in the wells as given in the table is in some cases only approximate, for usually there has been no means for accurately measuring it. Moreover, there is often more or less variation in the level from year to year, and the present level may be different from the one found at the time of observation.

Oklahoma

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	*Feet.*	*Feet.*	*Feet.*
*1	Beaver	Beaver	T. P. Braidwood	3	23	19	1890	48	20	18	− 18.0
*2	do	do	Ira S. Wilson	4	22	29	1900	6	18	12	− 4.5
3	do	Clear Lake	Frank Long	3	25	24	1901	48	34	32	− 32.0
4	do	Custer	D. T. Stanley	3	28	29	1889	54	12	8	− 8.0
5	do	Gate	W. J. Cunningham	5	28	35	1903	3	54	34	− 13.0
6	do	Guymon	E. C. Langston	3	15	31	1903	6	202	174	−172.0
7	do	do	Stonebreaker Zea Cattle Co.	2	14	23	1900	6	180	140	−100.0
8	do	do	J. G. Phagan	1	14	15	1902	54	43	40	− 40.0
*9	do	do	City well	3	15	31	1901	6	200	170	−170.0
10	do	Mineral	Jno. Skelley	4	1	13	1901	48	30	30	− 21.0
11	Blaine	Greenfield	I. E. P. Smith	15	12	35	1902	48	45	42	− 42.0
12	do	Homestead	C. N. R. R. (C. O. & G.).	[a]19	[a]11	....	1902	240	24	18	16.0
13	do	Judson	J. M. Scott	14	12	27	1895	6	127	90	− 90.0
14	do	Geary	D. Turner	14	12	8	1901	6	98	30	− 30.0
15	do	Ferguson	D. S. Schuber	18	11	23	1894	66	21	18	− 15.0
16	do	Judson	A. M. Hill	14	11	28	1901	8	83	35	− 35.0
17	do	Watonga	Thos. Remington	12	15	26	1900	7	110	40	− 40.0
*18	do	Geary	Ernest Truman	13	10	6	1903	12	127	20	− 20.0
19	do	Watonga	Geo. P. Forster	12	15	11	1897	6	60	45	− 22.0
20	do	do	W. L. Beal	15	12	25	1895	48	14	12	− 8.0
21	Caddo	Vrooman	Mrs. Lucy Green	9	13	7	1902	6	56	50	− 41.0
22	do	Laverty	Townsite Co	6	8	17	1902	6	136	100	− 80.0
23	do	Hydro	Jno. Dickson	12	12	25	1901	6	135	100	−100.0
24	do	Cement	S. A. Todd	5	9	2	1902	6	50	30	− 20.0
25	do	do	W. J. W. Patchell	5	3	30	1902	6	150	130	−120.0
26	do	Anadarko	C., R. I. and P. Ry. Co.	([a])	([a])	([a])	1902?	16	27	17	− 17.0
27	do	Boise	W. T. Motley	9	13	19	1901	6	70	50	− 50.0
28	do	Cement	W. H. Todd	5	9	25	1901	60	20	19	17.0
29	do	Libbie	M. E. West	12	13	35	1902	6	116	90	− 90.0
30	do	Hinton	Allen N. Hubbard	11	11	2	1902	8	177	175	−125.0
*31	Canadian	Elreno	N. J. Meyers	13	7	23	1896	48	43	39	− 38.0

* See notes at end of this table.

[a] City.

well records.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Hard	.....	Decreased (?).	Easy to lower	Permian	Permian	*1
do	do	.....	Neither	No effect	do	do	*2
Pump	Soft	0.5	do	Not easy to lower.	Tertiary	Tertiary	3
Mill and pump.	Hard	32.0	do	do	do	do	4
Pump	Soft	.....	do	do	do	do	5
Mill and pump.	do	10.0	do	do	do	do	6
do	do	10.0	do	do	do	do	7
Bucket	do	.5	do	Easy to lower	do	do	8
Mill and pump.	do	.....	do	Not easy to lower.	do	do	*9
do	do	4.0	do	Easy to lower with the pump in use.	Dakota Cretaceous.	Dakota Cretaceous	10
Bucket	Hard	.08	do	Not easy to lower.	Permian	Permian	11
Steam pump	Gypsif	4.8	do	Easy to lower	do	do	12
Mill and pump.	Soft	1.25	do	.....	do	do	13
do	do	2.77	do	Not easy to lower.	do	do	14
Bucket	Gypsif	.88	do	do	do	do	15
Mill and pump.	Soft	4.16	do	Not easily lowered.	Permian red beds.	do	16
do	Gypsif	.66	do	Not easy to lower.	Permian	do	17
.....	Hard	6.0	do	Easy to lower with the steam pump used in testing flow.	do	do	*18
Mill and pump.	Salty	10.0	do	Not easy to lower.	do	do	19
Bucket	Soft	.06	do	do	do	do	20
do	do	.02	do	Easy to lower	do	do	21
do	do	.4	do	Not easy to lower.	do	do	22
Pump	do	.....	do	do	do	do	23
Bucket	do	.02	do	Easy to lower	do	do	24
Mill and pump.	Hard	.15	do	Not easy to lower.	do	do	25
Steam pump	Soft	60.0	do	do	do	do	26
Pump	do	.06	do	do	do	do	27
Bucket	do	1.66	do	do	do	do	28
Mill and pump.	do	.22	do	do	do	do	29
do	do	5.3	do	do	do	do	30
do	Almost soft.	.....	do	do	do	do	*31

Oklahoma

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above
								In.	*Feet.*	*Feet.*	
*32	Canadian	Mustang	Frank Dotton	11	5	33	1896	6	32	20	—
33	do	do	S. E. Perkins	10	2	12	1892	48	44½	40	—
*34	do	Frisco	Jas. Smith	12	6	12	1899	4	78	33	—
*35		Elreno	W. J. Newland	11	7	11	1898	42	38	38	—
*36	do	Hinton	D. E. Bray	11	10	5	1901	8	119	90	—
37	do	Elreno	Luther Foster	13	7	23	1895	9	62	56	—
*38	do	do	J. C. Carter	13	7	15	1901	8	40	36	—
39	do	Calumet	Mr. Jerue	13	10	13	1902	5, 6	82	82	—
*40	do	Eda	Cecil Pratt	13	5	11	1902	8	45	40	—
*41	Cleveland	Moore	Public well	10	3W	14	1892	6	212	200	—
*42	do	Norman	University of Oklahoma.	9	2W	31	1903	8	282½	275	—
*43	do	Moore	Norman Milling and Grain Co.	10	3W	14	1902	6	193	183	—
*44	do	Morgan	George Foster	10	1W	18	1893	60	32	27	—
*45	do	Case	Thos. Shanley	10	1W	15	1889	4	20	17	—
*46	do	Oklahoma, well near Moore.	J. H. Smith	10	3W	7	1902	5	365	327	—
*47	do	Noble	W. Murphy	8	2W	27	1898	6	240	235	—
*48	do	Norman	R. C. Cain	(a)	(a)	(a)	1903	6	77	62	—
*49	do	Lexington	Herman Turk	10	3W	28	1900	6	269	258	—
*50	do	Moore	Kenneth McLennan.	10	3W	17	1899	6	262	250	—
51	Comanche	Nellie	Tom Watson	1N	9	12	1902	6½	51	39	—
52	do	Temple	Adolph Sorge	4S	10	24	1902	1¼	19	10	—
53	do	Sugden, Ind. T	Chas. Stone	5	8	30	1901	6	60	40	—
54	do	Lawton	J. P. Samplon	2S	9	....	1902	6	60	52	—
55	do	Hulin	Louis L. Young	1S	10	17	1902	72	21	13	—
*56	do	Hess	R. W. Briscoe	2	20	1	1890	54	50	50	—
57	do	Hastings	W. P. Corden	4	9	10	1902	36	18	16	—
*58	do	Duncan, Ind. T.	E. B. White	1	8	20	1902	6	18	15	—
*59	do	Cache	Frisco R. R. Co	2	14	24	1902	60	13	11	—
60	do	Baird	Scogins	1S	9	17	1902	6	45	30	—
61	Custer	Osceola	Joel Hudgens	15	18	21	1900	6	205	205	—
62	do	Weatherford	Jno. Bradshaw	12	15	15	1898	48	30	30	—
63	do	Swan	J. A. Ohls	14	14	27	1899	6	75	35	—
64	do	Osceola	Jake Vedder	15	19	22	1901	6	80	60	—
65	do	Gip	W. T. Hudgens	14	18	5	1900	6	96	85	—

*See notes at end of this table. a City.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Soft		Neither	Mill can run day and night.	Permian	Permian	*32
	Slightly hard.		Increased	Not easy to lower.	do	do	33
Mill and pump.	Salty		Neither		do	do	*34
do	Hard		Abundant supply.	Not easy to lower.	do	do	*35
Bucket	Soft	.044	Neither	Not easily lowered.	do	do	*36
do	Hard		do		do	do	37
Pump	do	.2		Easy to lower	do	do	*38
Mill and pump.	Soft		Abundant supply.	Not easy to lower.	do	do	39
Bucket	do		Neither	do	do	d0	*40
Mill and pump.	do	2.77	do	do	Red beds	Red beds.	*41
Steampump	Hard	11.69	do	do	do	do	*42
do	Soft	.55	do	do	do	do	*43
Bucket	Hard		do	do	do	do	*44
do	Soft		do	do	do	do	*45
Mill and pump.	do		do	do	do	do	*46
do	do	1.7	do	do	do	do	*47
Bucket	do	.11	do	do	do	do	*48
Pump	Alkali		do	do	do	do	*49
Mill and pump.	Alkaline	2.33	do	do	do	do	*50
Bucket	Soft	.044	do	do	Permian	Permian	51
Pump	Hard	.44	do	do	do	do	52
Bucket	Soft	.04	do	Easy to lower	do	do	53
do	Hard		do	Not easy to lower.	do	do	54
do	Soft	.55	do	do	do	do	55
Mill and pump.	Hard	2.66	Increased	do	do	do	*56
Bucket	Soft	1.0	Neither	do	do	do	57
do	Hard		do	Easy to lower	do	do	*58
Steam pump	Soft	22.5	do	Not easy to lower.	do	do	*59
Bucket	do		do	do	do	do	60
Mill and pump.	Gypsif	3.33	do	do	do	do	61
Bucket	Hard	1.16	do	do	do	do	62
Mill and pump.	Soft	.22	do	do	do	do	63
Bucket	Gypsif	.08	do	do	do	do	64
do	do	.22	do	do	do	do	65

Oklahoma well

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	*Feet.*	*Feet.*	*Feet.*
*32	Canadian	Mustang	Frank Dotton	11	5	33	1896	6	32	20	− 12.0
33	do	do	S. E. Perkins	10	2	12	1892	48	44¼	40	− 38.0
*34	do	Frisco	Jas. Smith	12	6	12	1899	4	78	33	− 18.0
*35		Elreno	W. J. Newland	11	7	11	1898	42	38	38	− 26.0
*36	do	Hinton	D. E. Bray	11	10	5	1901	8	119	90	− 90.0
37	do	Elreno	Luther Foster	13	7	23	1895	9	62	56	− 44.0
*38	do	do	J. C. Carter	13	7	15	1901	8	40	36	− 36.0
39	do	Calumet	Mr. Jerue	13	10	13	1902	5, 6	82	82	− 17.0
*40	do	Eda	Cecil Pratt	13	5	11	1902	8	45	40	− 4.0
*41	Cleveland	Moore	Public well	10	3W	14	1892	6	212	200	−112.0
*42	do	Norman	University of Oklahoma.	9	2W	31	1903	8	282¼	275	−232.5
*43	do	Moore	Norman Milling and Grain Co.	10	3W	14	1902	6	193	183	−123.0
*44	do	Morgan	George Foster	10	1W	18	1893	60	32	27	− 19.0
*45	do	Case	Thos. Shanley	10	1W	15	1889	4	20	17	− 10.0
*46	do	Oklahoma, well near Moore.	J. H. Smith	10	3W	7	1902	5	365	327	−110.0
*47	do	Noble	W. Murphy	8	2W	27	1898	6	240	235	− 90.0
*48	do	Norman	R. C. Cain	(a)	(a)	(a)	1903	6	77	62	− 37.0
*49	do	Lexington	Herman Turk	10	3W	28	1900	6	269	258	−100.0
*50	do	Moore	Kenneth McLennan.	10	3W	17	1899	6	262	250	− 25.0
51	Comanche	Nellie	Tom Watson	1N	9	12	1902	6¼	51	39	− 31.0
52	do	Temple	Adolph Sorge	4S	10	24	1902	1¼	19	10	− 10.0
53	do	Sugden, Ind. T	Chas. Stone	5	8	30	1901	6	60	40	− 30.0
54	do	Lawton	J. P. Samplon	2S	9	....	1902	6	60	52	− 44.0
55	do	Hulin	Louis L. Young	1S	10	17	1902	72	21	13	− 10.0
*56	do	Hess	R. W. Briscoe	2	20	1	1890	54	50	50	− 48.0
57	do	Hastings	W. P. Cordell	4	9	10	1902	36	18	16	− 15.0
*58	do	Duncan, Ind. T	E. B. White	1	8	20	1902	6	18	15	− 15.0
*59	do	Cache	Frisco R. R. Co	2	14	24	1902	60	13	11	− 7.0
60	do	Baird	Scogins	1S	9	17	1902	6	45	30	− 25.0
61	Custer	Osceola	Joel Hudgens	15	18	21	1900	6	205	205	90.0
62	do	Weatherford	Jno. Bradshaw	12	15	15	1898	48	30	30	− 27.0
63	do	Swan	J. A. Ohls	14	14	27	1899	6	75	35	− 35.0
64	do	Osceola	Jake Vedder	15	19	22	1901	6	80	60	− 50.0
65	do	Gip	W. T. Hudgens	14	18	5	1900	6	96	85	− 75.0

*See notes at end of this table. a City.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Soft		Neither	Mill can run day and night.	Permian	Permian	*32
	Slightly hard.		Increased	Not easy to lower.	do	do	33
Mill and pump.	Salty		Neither		do	do	*34
do	Hard		Abundant supply.	Not easy to lower.	do	do	*35
Bucket	Soft	.044	Neither	Not easily lowered.	do	do	*36
do	Hard		do		do	do	37
Pump	do	.2		Easy to lower	do	do	*38
Mill and pump.	Soft		Abundant supply.	Not easy to lower.	do	do	39
Bucket	do		Neither	do	do	d0	*40
Mill and pump.	do	2.77	do	do	Red beds	Red beds.	*41
Steam pump	Hard	11.69	do	do	do	do	*42
do	Soft	.55	do	do	do	do	*43
Bucket	Hard		do	do	do	do	*44
do	Soft		do	do	do	do	*45
Mill and pump.	do		do	do	do	do	*46
do	do	1.7	do	do	do	do	*47
Bucket	do	.11	do	do	do	do	*48
Pump	Alkali		do	do	do	do	*49
Mill and pump.	Alkaline	2.33	do	do	do	do	*50
Bucket	Soft	.044	do	do	Permian	Permian	51
Pump	Hard	.44	do	do	do	do	52
Bucket	Soft	.04	do	Easy to lower	do	do	53
do	Hard		do	Not easy to lower.	do	do	54
do	Soft	.55	do	do	do	do	55
Mill and pump.	Hard	2.66	Increased	do	do	do	*56
Bucket	Soft	1.0	Neither	do	do	do	57
do	Hard		do	Easy to lower	do	do	*58
Steam pump	Soft	22.5	do	Not easy to lower.	do	do	*59
Bucket	do		do	do	do	do	60
Mill and pump.	Gypsif	3.33	do	do	do	do	61
Bucket	Hard	1.16	do	do	do	do	62
Mill and pump.	Soft	.22	do	do	do	do	63
Bucket	Gypsif	.08	do	do	do	do	64
do	do	.22	do	do	do	do	65

Oklahoma w

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (—) mouth of well.
								In.	*Feet.*	*Feet.*	*Feet.*
66	Custer	Etna	Louis Sturgis	12	14	7	1901	6	125	75	—75.0
67	do	Elm	Frank Davis	15	18	24	1901	6	142	112	—112.0
68	do	Butler	N. L. Blake	14	20	12	1901	6	182	164	—144.0
69	do	do	H. E. Reynolds	13	19	13	1898	8	165	120	—105.0
70	do	Arapahoe	Marion Lucas	14	16	30	1898	6	120	90	— 45.0
71	Day	Arnett	Herman Schultz	19	24	7	1901	42	42	37	— 37.0
72	do	Reason	Jno. Reed	18	23	24	1902	6	171	165	— 20.0
73	do	Craft	C. M. Atwood	19	24	2	1903	42	111	107	—107.0
74	do	Grand	Cleo Paine	17	24	21	1902	8	121	103	—103.0
*75	do	Gage	Pearley Cloyd	19	23	1	1902	40	126	123	—123.0
*76	do	Arnett	J. E. Brown	19	24	16	1902	2	182	180	—160.0
*77	do	Shattuck	Schultz	19	25	1	1901	48	56	54	— 53.0
78	do	Arnett	A. C. Beattie	19	24	20	1901	6	164	164	—134.0
79	do	Craft	P. F. Bradshaw	19	24	3	1902	2	146	106	—106.0
80	do	do	I. W. Fortney	19	24	10	1901	48	57	57	— 55.0
*81	Dewey	Burmah	Ben Oswald	17	17	32	1902	48	30	23	— 23.0
82	do	Fay	Wm. A. Boyd	16	14	27	1901	6	90	70	— 70.0
83	do	Jacks	Arthur Jewett	16	14	13	1900	6	186	158	—158.0
84	do	Lenora	B. P. Mayfield	17	18	1	1900	6	98	98	— 48.0
85	do	do	A. M. Towner	17	18	13	1891	6	171	.....	—100.0
86	do	Putnam	A. E. Agee	17	17	25	1900	6	128	90	— 80.0
87	do	Raymond	W. H. Dodson	17	18	35	1900	48	45	42	— 42.0
88	do	Roseland	M. L. Drake	16	16	16	1902	6	47	41	— 41.0
89	do	Deltis	Geo. W. Harris	17	19	27	1902	6	140	140	—120.0
90	do	Webb	Henry Schultz	17	18	29	1902	6	112	100	—100.0
*91	Garfield	Glenella	G. L. Bushwisel	23	8	31	1895	6	40	29	— 29.0
92	do	Waukomis	H. T. Roach	21	6	22	1895	48	12	12	— 8.0
*93	do	Garber	Wm. Walker	23	4	27	1893	6	30	20	— 20.0
94	do	Waukomis	C. White	20	6	3	1894	6	41½	22	— 22.0
*95	do	Carrier	J. C. Palmer	23	8	17	1900	6	31	28	— 28.0
96	do	Billings	C. C. Rosencrants	23	3	3	1895	48	30	+25	— 25.0
97	do	Waukomis	Chas. Thain	21	7	27	1895	48	73	72	— 60.0
*98	do	Carrier	John Pope	24	8	11	1893	36	10	10	— 8.0

*See notes at end of this table.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Soft	.44	Neither	Not easy to lower.	Permian	Permian	66
Bucket	Gypsif	.08	do	Easy to lower	do	do	67
Mill and pump.	Hard	.44	do	Not easy to lower.	do	do	68
do	Gypsif	.111	do	Easy to lower	do	do	69
Bucket	Hard	.111	do	Not easy to lower.	do	do	70
Pump	Soft	4	do	do	Tertiary	Tertiary	71
Mill and pump.	Gypsif		do	do	Permian	Permian	72
do	Hard	2.0	do	do	Tertiary	Tertiary	73
do	Soft	5.5	do	do	do	Permian(?)	74
Bucket	do	.5	do	Easy to lower	do	Tertiary(?)	*75
Mill and pump.	do	1.116	do	Not easy to lower.	do	do	*76
Bucket	do	.06	do	Easy to lower	do	do	*77
Mill and pump.	do	20.0	do	Not easy to lower.	do	do	78
Pump	do	3.0	do	do	do	do	79
Bucket	do	.133	do	do	do	do	80
do	Hard, a little salty.	.66	do	Easy to lower	Permian	Permian	*81
Mill and pump.	Soft	.44	do	do	Tertiary	Tertiary	82
Bucket	Hard	2.0	do	Not easy to lower.	do	do	83
Mill and pump.	Gypsif	1.66	do	do	Permian	Permian	84
do	do	.26		Easy to lower	do	do	85
Bucket	Alkaline	.5	Increased	do	do	do	86
do	Gypsif	.04		Not easy to lower.	do	do	87
Mill and pump.	do	.44	Increased	do	do	do	88
Pump	Soft	.22	do	do	do	do	89
Bucket	Hard	.44		do	do	do	90
Mill and pump.	do	.22	Increased	Not easily lowered.	do	do	*91
do	Soft	2.22	Neither	Can't pump out water.	do	do	92
Pump	Hard		do	Runs in as fast as pumped out.	do	do	*93
	Slightly salty.	.333	do	Not easy to lower.	do	do	94
Mill and pump.	Hard		do	Can't lower	do	do	*95
Bucket	Soft		do	Easy to lower	do	do	96
Pump	Hard	.5	do	Lowers level.	do	do	97
Mill and pump.	Soft		do	Can't lower	do	do	*98

Oklahoma we

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	*Feet.*	*Feet.*	*Feet.*
*99	Garfield	Kremlin	H. D. Lacy	24	7	20	1894	48	18	14	− 13.
100	do	Lahoma	Chas. B. Longcor	21	8	7	1898	48	36	36	− 30.
*101	Grant	Numa	O. J. Wilkison	27	4	9	1896	48	23	12	− 8.
*102	do	Florence	D. M. Thomas	27	8	18	1903	3	59	56	− 3.
*103	do	Gibbon	J. A. Johnson	29	7	28	1902	6	25	11	− 7.
*104	do	Deer Creek	W. H. Raymond	26	3	10	1895	72	45	45	− 32.
*105	do	Pond Creek	V. Rapp	27	8	14	1903	1¼	71	6	− 8.
*106	do	Renfrow	T. H. Paris	28	3	19	1894	72	48	40	− 10.
*107	do	Manchester	C. W. Alley	29	7	18	1893	12	40	22	− 20.
*108	do	Jefferson	C. T. James	26	5	14	1897	1¼	35	35	− 18.
*109	do	Renfrow	C. W. Foetisch	28	4	22	1899	6	93	85	− 35.
*110	do	Lamont	D. P. Moffett	26	3	33	1899	48	28	−28	− 8.
111	do	Medford	W. S. Robertson	27	5	22	1894	48	23	6	− 4.
112	Greer	Martin	John Brim	2N	25	29	1900	6	63	60	− 43.
113	do	do	L. P. Tyler	1	25	17	1901	6	105	94	− 97.
114	do	Mangum	C., R. I. and P. Ry.	(a)	(a)	(a)	1902	192	30	30	− 30.
115	do	Hollis	J. M. Prock	2	26	15	1900	7	96	90	− 87.
116	do	do	W. J. Branigan	3	26	11	1902	6	120	75	− 60.
*117	do	Doans, Tex	S. B. Everett	2	20	13	1898	48	10	10	− 8.
118	do	Greer	W. C. West	2	25	14	1901	6	30	30	− 30.
119	do	Duke	Stirling Soloman	2 N	23	27	1902	6	57	53	− 40.0
120	do	Carl	J. A. Kinjkendall	6	26	23	1901	42	37½	34	− 34.0
121	do	Salton	Isaac C. Stewart	6	25	6	1901	72	44	40	− 34.0
*122	Kay	Newkirk	City	28	2 E	26	1901	360	45	42	− 35.0
*123	do	Ponca City	Oscar Taylor	26	2 E	32	1894	2	25	23	− 23.0
*124	do	Uncas	M. L. Devore	27	3 E	24	1898	60	47	44	− 44.0
*125	do	Tonkawa	A. H. Miller	25	1W	19	1895	36	12	11	− 8.0
*126	do	Eddy	W. High	25	2W	5	1894	36	18	14	− 14.0
*127	do	do	J. B. Bush	26	2W	29	1902	6	88	70	− 20.0
*128	do	Kildare	S. Spore	27	2 E	9	1898	72	40	38	− 18.0
*129	do	Tonkawa	Samuel Stahl	25	1W	19	1901	8	40	38	− 28.0
*130	do	Blackwell	N. D. Kistler	26	1	2	1897	1¼	30	26	− 26.0
*131	do	Nardin	John McFarlin	27	2W	30	1897	6	47	36	− 31.0
132	Kingfisher	Kiel	Geo. Jameson	17	8	8	1898	60	12	8	− 4.0
133	do	Kingfisher	Mrs. N. L. St. Clair	17	7	7	1902	60	35	33	− 25.0
134	do	Dover	Wm. Homier	17	7	18	1898	60	34	32	− 28.0

*See notes at end of this table.

a City.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Hard	.66	Neither	Not easily lowered.	Permian	Permian	*99
Bucket	Soft		do	Not easy to lower.	Tertiary	Tertiary	100
Pump	Salty		do	Goes down	Permian	Permian	*101
do	Soft		do	Constant	Tertiary	Tertiary	*102
do	Hard		do	Easy to lower.	Permian	Permian	*103
Mill and pump.	do		do	Can be lowered.	do	do	*104
Pump	Soft		Varies with the season.	None	Tertiary	Tertiary	*105
	Hard		Varies	To lower	Permian	Permian	*106
Bucket	do		About the same.	Lowered	do	do	*107
Windmill	Soft		Constant	Not affected	do	do	*108
Pump	Hard		About the same.	Lower	do	do	*109
do	do		Neither	Can't pump dry.	do	do	*110
Flowing	Salt		do	Can be lowered.	do	do	111
Mill and pump.	Gypsif	3.33	do	Not easy to lower.	do	do	112
do	Salty		do	do	do	do	113
do	Soft	30.0	do	do	do	do	114
do	Hard	.66	do	do	do	do	115
do	Gypsif	.88	do	do	do	do	116
Bucket	Hard	2.66	do	do	do	do	*117
Mill and pump.	do	.22	do	do	do	do	118
Bucket	Gypsif	1.37	do	do	do	do	119
do	Hard	.11	do	Easy to lower	do	do	120
Mill and pump.	Gypsif	.08	do	Not easy to lower.	do	do	121
Steam pump	Soft	11.8	do	do	do	do	*122
Mill and pump.	do		do	Mill runs day and night.	do	do	*123
do	do	.42	do	Not easy to lower.	do	do	*124
Pump	Hard and salty.	.083	do	Easily lowered.	do	do	*125
Mill and pump.	Hard	3.33	do	Not easy to lower.	do	do	*126
do	do		do	do	do	do	*127
do	do		do	do	do	do	*128
Pump	Alkaline	.055	do	Easy to lower	do	do	*129
do	Soft	7.0	do	Can not lower	do	do	*130
Mill and pump.	do	4.0	do	Not easy to lower.	do	do	*131
do	Hard	4.0	do	do	do	do	132
do	do	.133	do	do	do	do	133
do	do	5.0	do	do	do	do	134

Oklahoma wells

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	*Feet.*	*Feet.*	*Feet.*
135	Kingfisher	Dover	Harvey Jameson	17	8	2	1902	60	17	11	− 5.0
136	do	Cashion	R. A. Bryant	15	5	12	1901	6	55	55	− 45.0
137	do	do	B. F. Harmon	15	5	15	1901	6	52	43	− 40.0
138	do	do	S. S. Cole	15	5	12	1901	8	55	50	− 43.0
139	do	Parvin	A. W. Parvin	19	9	33	1892	42	20	13	− 8.0
140	do	Hennessey	J. O. Wright	20	6	33	1890	36	14	13	− 1.0
141	do	Wandel	J. W. Crum	17	5	3	1904	1¼	15	10	− 10.0
142	Kiowa	Lone Wolf	D. C. Bruce	5	19	18	1903	56	10	8	− 8.0
143	do	Mountain Park.	J. Campbell	3	17	22	1903	8	21	14	− 4.0
144	do	Chadwick	D. P. Churchwell	1 N	19	23	.....	3.6	12	10	− 10.0
145	do	Lone Wolf	A. B. Shelton	6	19	35	1903	60	17	16	− 10.0
146	do	Harrison	Jas. H. Lister	7	15	6	1902	8	19	20	− 12.0
147	do	Nesbitt	Willis Stanfill	7	5	7	.....	42	37	35	.....
148	do	Mountain Park.	Lewis Vilnen	4	16	35	1902	60	19	16	− 10.0
149	do	Cloverton	J. A. Willits	3 N	16	1	1902	60	18	13	− 13.0
150	do	Hobart	Wm. H. Pearl	6	17	5	1902	48	28	26	− 22.0
*151	do	Snyder	C. T. Gorton	2 N	17	11	1902	6	26	20	− 16.0
*152	Lincoln	Carney	Wm. Bedford	16	3 E	20	1902	6¼	103¼	100	− 53.5
*153	do	Tryon	Jones	16	2 E	18	1902	6¼	141	85¼	− 75.5
*154	do	do	J. H. Harter	16	4 E	8	1902	6¼	103¼	100	− 78.5
*155	do	Fallis	Joe Dufraine	15	2 E	28	1900	6	40	38	− 22.0
*156	do	Riddle	C. A. Sherwin, sr.	12	4 E	26	1894	36	22	20	− 17.0
*157	do	do	C. A. Sherwin, jr.	12	4 E	34	1901	6	124	115	−104.0
*158	do	Clifton	Farmers' Gin Co.	12	4 E	20	1902	120	36	36	− 16.0
*159	do	Wellston	G. W. Blakeley	16	2 E	19	1895	7	45	39	− 29.0
*160	do	Perkins	Jose Hert	17	3 E	22	1901	6¼	72	68	− 52.0
*161	do	Clifton	I. C. Boulson	12	4	33	1903	6	57	45	− 35.0
*162	Logan	McKinley	David Swank	16	1 E	34	1893	8	92	86	− 76.0
*163	do	Coyle	O. L. Jewitt	18	1 E	30	1898	60	54	54	− 50.0
*164	do	McKinley	D. K. Campbell	16	1 E	27	1893	10	85	80	− 70.0
*165	do	Mulhall	J. H. Wesley	18	3W	9	1899	8	52	37	− 32.0
*166	do	Langston	Freeman Wallace	17	1 E	22	1902	6	63	50	40.0
167	do	Crescent	A. C. Ringold	17	3W	31	1893	60	28	21	− 21.0

*See notes at end of this table.

—Continued.

ob-ed at ace.	Quality.	Supply per minute	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
and p.	Hard, nearly soft.	40.0	Neither	Not easy to lower.	Permian	Permian	135
	Soft	10.0	do	do	do	do	136
	Hard		do	do	do	do	137
	Soft		do	do	do	do	138
t	do		do	do	do	do	139
	do		do	do	do	do	140
	Salty		do	do	Tertiary	Tertiary	141
t	Gypsif		do	Easy to lower	Permian	Permian	142
	Soft		do	Not easy to lower.	do	do	143
et	do		do	Easy to lower	do	do	144
	Salty		do	do	do	do	145
	Soft		Increased	Not easy to lower.	do	do	146
	Hard		Neither	Easy to lower	do	do	147
et	Soft	.04	do	Not easy to lower.	do	do	148
o	do		do	Easy to lower	do	do	149
o	do	.02	do	Not very easy to lower.	do	do	150
ps	Salty and soda.	.04	do	Not easy to lower.	do	do	*151
et	Soft	3.0	do	Can be lowered to 23 feet.	Red beds	Red beds	*152
	do	2.2	do	Not easy to lower.	do	do	*153
et	do		do	Not easily lowered.	do	do	*154
lo	do		do	Not easy to lower.	do	do	*155
lo	Hard	.44	do	do	do	do	*156
lo	Soft		do	Easy to lower	do	do	*157
n pump	do	3.33	do	Not easy to lower.	do	do	*158
et	Medium soft.		do	do	do	do	*159
p	Hard	1.66	do	do	do	do	*160
et	do		do	do	do	do	*161
and np.	do		do	Easily lowered.	Permian	Permian	*162
o	do	.83	do	Easy to lower.	do	do	*163
et	Soft		do	Is easily lowered.	do	do	*164
p	Hard	.14	do	Not easy to lower.	do	do	*165
and np.	do	.087	do	Easily lowered.	do	do	*166
	do	.27	Increase	Can be pumped dry in 4 hours.	do	do	167

Oklahoma w

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	*Feet.*	*Feet.*	*Feet.*
*168	Logan	Guthrie	Jas. Knox	16	1W	14	18[illegible]2	7	150	70	− 70.0
*169	do	Mulhall	Peter Beleele	18	3W	5	1901	8	42	41	− 21.0
*170	do	Crescent	John Wilson	17	4W	22	1890	48	85	75	− 45.0 to − 65.0
*171	do	Coyle	C. W. Longan	17	1 E	4	1902	8	91	80	− 70.0
172	Noble	Ceres	W. A. Chessher	23	1W	11	1896	66	28	18	− 12.0
173	do	Day	A. Seals	21	2 E	26	1897	6	40	27	− 20.0
174	do	Perry	M. M. Barnard	21	1W	24	1900	8	104	90	− 10.0
*175	do	Ceres	E. J. Waltermire	23	1W	22	1899	6	40	37	− 15.0
*176	do	Billings	J. J. Lentz	23	3W	14	1900	6	70	55	− 35.0
*177	do	Orlando	Geo. Ketch	20	2W	25	1895	8	132	102	− 82.0
*178	do	Burton	J. E. Writt	24	1W	7	1901	7	47	12	− 11.0
*179	do	Morrison	Hull Bros	21	3 E	17	1903	7	110	100	− 30.0
*180	do	Billings	Jay R. Graves	23	3	14	1902	6	181	180	− 16.0
181	do	Perry	Henry Koelzer	21	1 E	30	1901	48	53	52	− 17.0
*182	Oklahoma	Choctaw	John Quim	12	1W	34	1902	6	54	37	− 37.0
*183	do	Luther	Lee Dalrymple	13	1 E	28	1903	6	64	42	− 42.0
*184	do	Britton	Henry Hasley	13	3W	31	1900	10	160	155	−100.0
*185	do	Choctaw	J. A. Kennedy	12	1 E	29	1900	10	71	45	− 45.0
186	do	do	Carrie Miller	12	1W	23	1902	10	34	22	− 22.0
*187	do	Jones City	C. A. Chandler	12	1 E	9	1900	6	112½	100	− 95.0
*188	do	do	Homer Britton	13	1 E	20	1903	6	58	41	− 40.0
*189	do	Oklahoma	W. F. Young	13	1W	25	1903	6	68	60	− 50.0
190	do	Luther	Grant Stanley	14	1 E	25	1896	10	78	60	− 60.0
*191	do	Jones City	C. H. McLung	12	1W	3	1903	6	43	38	− 28.0
*192	Pawnee	Pawnee	Lone Chief	22	6 E	18	1894	6	42	28	− 27.0
*193	do	Glencoe	S. Vandment	21	4 E	32	1895	10	77	75	− 67.0
*194	do	Masham	W. C. Legrande	23	4 E	34	1894	6	82	77	− 37.0
*195	do	do	B. F. Harmon	26	4 E	24	1901	8	28	26	− 18.0
*196	do	Pawnee	E. C. Wheeler	23	5 E	35	1899	6	136	134	− 66.0
*197	do	Masham	J. S. Stritch	29	4 E	26	1894	60	12	8	− 6.0
*198	do	Pawnee	Louis Demieville	22	5 E	5	1896	7	46	23	− 23.0
*199	do	Filson	Fred Strobal	23	5 E	18	1899	6	40	32	− 32.0
*200	do	Pawnee	L. P. Botts	22	5 E	4	1897	7	65	40	− 40.0
*201	do	Ralston	Jas. Bogle	23	5 E	12	1899	2	21½	20	− 19.5
*202	Payne	Westpoint	Hiram B. Allnutt	20	4 E	22	1901	7	45	18	− 18.0

*See notes at end of this table.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No
		Gals.					
Bucket	Soft	.135	Neither	Easily lowered.	Permian	Permian	*16
Pump	Hard		do	Not easy to lower.	do	do	*16
Bucket	Soft	10.4	Increase	do	do	do	*17
do	do		Neither	Not easily lowered.	do	do	*17
Mill and pump.	Hard	.13	do		do	do	17
Bucket	do		do		do	do	17
Mill and pump.	do		do	Easy to lower	do	do	17
do	Alkaline		do	Can not lower	do	do	*17
Bucket	do		do	Easy to lower	do	do	*17
Mill and pump.	Salty	14.0	do	do	do	do	*17
Pump	Soft	1.33	do		do	do	*17
	do		do	Not easily lowered.	do	do	*17
Bucket	do	4.16	do	do	do	do	*18
Mill and pump.	do	.266	do	Easily lowered.	do	do	18
Bucket	do		do	Easy to lower	Red beds	Red beds	*18
do		2.0	do	Easily lowered.	do	do	*18
Mill and pump.	Hard and salty.	10.0	do	Easy to lower	do	do	*18
do	Hard		do	Not easy to lower.	do	do	*18
Bucket	Soft	4.16	do	do	do	do	18
do	do		Decreased	Easily lowered.	do	do	*18
Pump	Hard	1.66	Neither	Easy to lower	do	do	*18
Bucket	do	3.33	do	Not easy to lower.	do	do	*18
Pump	do	4.0	do		do	do	19
Bucket	do	2.5	do	Easy to lower	do	do	*19
do	Soft		do	Not easy to lower.	Pennsylvanian.	Pennsylvanian	*19
do	Salty			Easy to lower	do	do	*19
Pump	Soft		Decreased	do	do	do	*19
Bucket	do		Neither	do	do	do	*19
Mill and pump.	do	1.3	do	Not easy to lower.	do	do	*19
Bucket	Hard		do	do	do	do	*19
Pump	do	.13	do	do	do	do	*19
Bucket	Soft	.03	do	Easy to lower	do	do	*19
do	do	.03	do	do	do	do	*20
Mill and pump.	do	6.6	do	Not easy to lower.	do	do	*20
Bucket	do		do	Easy to lower	Red beds	Red beds	*20

Oklahoma w

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) [illegible]
								In.	*Feet.*	*Feet.*	*Feet.*
*203	Payne	Lawson	Reuben Wilson	19	5 E	14	1901	48	26	22	− 22.0
*204	do	Ingalls	S. T. Kirby	19	5 E	20	1897	6	20	18	− 8.0
*205	do	Stillwater	O. F. Weaver	18	1 E	2	1891	60	42	22	− 22.0
*206	do	Ingalls	Frank A. Henderson.	19	5 E	23	1901	7	140	138	− 80.0
*207	do	Glencoe	F. C. Jessee	20	4 E	31	1902	6¼	60	50	− 40.0
*208	do	Westpoint	Wm. Dodd	20	4 E	7	1895	6	104	102	− 49.0
*209	do	Ripley	John F. Oldham	18	4 E	20	1892	8	77	66	− 66.0
*210	do	Marena	R. C. McKee	19	1 E	34	1895	48	21	20	− 16.0
*211	do	Perkins	J. W. Carr	18	3 E	34	1895	9	50	43	− 23.0
212	Pottawatomie	Moral	W. B. Trousdale	7	3 E	21	1902	6	130	127	− 40.0
213	do	Bellmont	Edgar Mack	11	4 E	2	1903	6	137	130	−107.0
214	do	do	L. D. Cavins	11	4 E	2	1902	6	81	71	− 65.0
215	do	Moral	J. S. Lamm	7	2	12	1893	6	84	80	− 70.0
*216	do	do	J. W. Foster	7	3 E	19	1893	6	50	40	− 15.0
217	do	do	B. I. Martin	7	3 E	18	1898	6	48	44	− 36.0
*218	do	Shawnee	J. H. Wallace	10	3 E	18	1899	6	135	130	− 65.0
*219	do	Bellmont	Dick Quinn	11	4 E	4	1902	6	90	85	− 74.0
*220	do	do	Hugh Woklee (Indian).	11	4 E	3	1903	6	62	55	− 46.0
*221	do	Anderson	J. E. Jarman	7	3 E	15	1892	6	95	90	− 70.0
222	Roger Mills	Doxey	J. Hilderbrand	10	22	8	1901	8	144	43	− 43.0
223	do	Ural	T. J. McReynolds	....	21	....	1904	6	62	54	− 35.0
224	do	Carter	Jno. King	9	22	35	1898	36	40	35	− 30.0
225	do	Poarch	Jas. Adkerson	8	21	11	1900	60	18	15	− 15.0
226	do	Grimes	W. L. Blackburn	12	24	27	1902	6	110	95	− 95.0
227	do	Berlin	Wm. Kohn	12	23	19	1902	6	132	120	−120.0
228	do	Grimes	T. L. Sherrill	11	24	19	1902	7	30	28	− 24.0
229	do	Berlin	F. E. Richardson	12	24	13	1902	6	119½	103½	− 93.0
230	do	Elk City	J. W. McDonald	11	20	19	1898	60	27	24	− 8.0
231	do	Grimes	I. F. Meeks	12	24	32	1901	72	33	30	− 27.0
232	Washita	Cowden	Jas. Rhodes	9	14	20	1900	6	86	60	− 60.0
233	do	Burns	J. A. Jester	10	19	14	1900	6	65	44	− 40.0
234	do	Shelly	C. Ediger	11	16	14	1898	7	200	180	− 60.0
235	do	Cordell	John T. Dazey	10	18	32	1899	36	31	30	− 23.0
236	do	Rainy	A. B. Brown	8	17	24	1902	6	184	128	−128.0
237	do	Boise	S. A. Gamble	9	14	24	1902	6	113	100	− 90.0
238	do	Burns	Browers	9	19	5	1898	42	18	17	− 14.0

*See notes at end of this table.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Pump	Hard	.02	Neither	Not easy to lower.	Red beds	Red beds	*203
Bucket	do		do	do	do	do	*204
do	Soft		do	do	do	do	*205
Pump	do	.11	do	do	do	do	*206
	do		do	do	do	do	*207
Mill and pump.	do		do	do	do	do	*208
do	do		do	Easy to lower	do	do	*209
Bucket	Hard	.166	do	Not easy to lower.	do	do	*210
Mill and pump.	Soft	.55	do	Easy to lower	do	do	*211
Bucket	do		do	Not easy to lower.	do	do	212
do	Hard		do	do	do	do	213
do	do		do	do	do	do	214
do	do		do	do	do	do	215
do	do	.1	do	Easy to lower	do	do	*216
do	do	1.0	Increased		do	do	217
do	do	.05	Neither	Easily lowered.	do	do	*218
do	Soft		do	Not easily lowered.	do	do	*219
do	Hard		do	do	do	do	*220
do	Soft	1.33	do	Easily lowered.	do	do	*221
do	Hard		do	Easy to lower	Permian	Permian	222
do	do		do	do	do	do	223
Mill and pump.	do		do	Not easy to lower	do	do	224
Bucket	Gypsif		do		do	do	225
do	Soft	1.66	do	Easy to lower	do	do	226
Pump	do	[illegible]	do	Not easy to lower	do	do	227
Bucket	do	.016	do	Easy to lower	do	do	228
do	do	.04	do	Not easy to lower	do	do	229
Pump	do	21.3	do	do	do	do	230
Bucket	do	[illegible]	do	Easy to lower	do	do	231
Mill and pump.	Hard	[illegible]	do	Not easy to lower	do	do	232
do	Soft	[illegible]	do	[illegible]	do	do	233
Bucket	Hard. salty.		do	Not easy to lower	do	do	234
do	Hard	[illegible]	do	[illegible]	do	do	235
Pump	Soft	[illegible]	do	[illegible]	do	do	236
Bucket	do	[illegible]	do	[illegible]	do	do	237
do	do	[illegible]	Increased	Easy to lower	do	do	238

Oklahoma

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above [illegible]
								In	*Feet.*	*Feet*	*Fe*
239	Washita	Burns	J. N. Arnold	10	19	20	1898	66	30	26	1
240	do	Korn	P. Settkeman	11	15	7	1902	48	12	10	–
241	do	Kiel	Geo. Jameson	8	17	8	1895	42	13	8	
242	Woods	Amorita	Henry Witte	29	10	31	1896	1¼	40	27	– 2
243	do	Ringwood	Jonah Grieve	22	10	4	1894	54	60	55	– 4
244	do	Helena	Edgar Hubbel	24	10	16	1901	6	72	70	– 3
245	do	Ingersoll	C. Haas	27	11	29	1894	2	27	20	– 1
246	do	Cherokee	J. T. Millspaugh	26	11	3	1894	1¼	32	16	1
*247	do	Alva	R. C. Brown	(a)	(a)	(a)	1901	6	123	83	– 6
248	do	Auburn	C. M. Ingram	26	12	1	1896	10	51	45	– 3
249	do	Byron	W. F. Brown	28	10	9	1901	2	30	28	– 1
250	do	Chester	Frank Forward	20	16	8	1900	10	65	50	– 5
251	do	Concord	Geo. Picler	22	10	1	1902	3	144	85	– 6
252	Woodward	Oleta	G. W. Sleeth	22	23	31	1896	3	40	45	– 3
253	do	Speermore	E. E Strohmeier	25	25	30	1901	42	25	24	– 2
254	do	Belva	R. A. Doles	23	17	1	1901	72	27	23	– 2
255	do	Waynoka	J. J. Russell	25	17	26	1901	48	35	24	– 2
256	do	Oleta	Martha N. Smith	21	22	1	1895	72	18	12	– 1
257	do	Speermore	Aaron Hartfield	25	26	26	1902	6	78	78	– 7
258	do	Laverne	Geo. W. Ralls	26	25	28	1901	1¼	35	34	– 3
259	do	Shattuck	A., T. & S. F. Ry	(a)	(a)	(a)	1887	96	95	35	– 3
260	do	Curtis	Wm. Martindale	22	18	24	1901	10	112	110	–10
261	do	Detroit	O. A. Nickerson	21	20	17	1902	24	91	89	– 8

* See notes at end of this table. (a) City.

cords—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Bucket	Soft	2.0	Neither	Not easy to lower.	Permian	Permian	239
do	Hard	.83	do	do	do	do	240
Mill and pump.	do		do	Can not lower	do	do	241
Pump	do	5.0	do	Not easy to lower.	do	do	242
Bucket	do		Increased	Easy to lower	Tertiary	do	243
Pump	do	2.2	Neither	Not easy to lower.	Permian	do	244
Mill and pump.	do	2.22	do	do	do	do	245
Pump	do	.22	do	do	do	do	246
do	Gypsif	.4	Decreased	Easy to lower	do	do	*247
Mill and pump.	Soft	.3	Neither	do	do	do	248
do	do	.22	do	Not easy to lower.	Tertiary	Tertiary	249
do	do	6.6	do	do	do	do	250
Pump	do	.22	do	do	do	do	251
do	do	.03	do	Not easily lowered.	do	do	252
do	do	.06	do	Easy to lower	do	do	253
do	Hard		do	Not easily lowered.	Permian	Permian	254
do	Salt		do	Easy to lower	do	do	255
do	Hard	.03	do	do	Tertiary	Tertiary	256
do	Soft	.17	do	Not easy to lower.	do	do	257
do	do		do	Not easily lowered.	Permian	Permian	258
Steam pump	Hard	69.44	do	Easy to lower with sand pump.	Tertiary	Tertiary	259
Mill and pump.	Soft	.05	do	Easy to lower	Permian	Permian	260
Pump	do	.03	do	Not easily lowered.	Tertiary	Tertiary	261

NOTES ON WELLS OF OKLAHOMA.

No. 1. Flows an inch stream nearly all the time.

No. 2. Tertiary sands are mixed with the Permian to some extent.

No. 9. The water from this well is hauled for miles by the settlers, many of whom have no other water near. The location is given from the Cimarron meridian (103°). Water analysis No. 2.

No. 18. This is a test well. Pump was removed.

No. 31. Water in sand and gravel.

No. 32. Water in gravel.

No. 34. Water in red sand.

No. 35. Water in shale.

No. 36. Water in shelly sand rock.

No. 38. Water in sand.

No. 40. Water in sandy gravel.

No. 41. Water in sand.

No. 42. Water in sandstone. Water contains iron, Glauber's salt, chlorine, and perhaps other elements. Water analysis No. 22.

Nos. 43 and 44. Water in sand.

No. 45. Water in clay.

No. 46. Water in coarse sandstone.

No. 47. Water in gravel.

No. 48. Water in sandstone.

No. 49. Water in sand.

No. 50. Surface water in clay at 25 feet, main supply in sand rock.

No. 56. Used to irrigate garden.

No. 58. The well is in Oklahoma.

No. 59. Temporary watering station.

No. 75. Well is in Day County. Post-office in Woodward County.

No. 76. The owner says the amount is inexhaustible.

No. 77. The well is in Day County. Post-office in Woodward County. The above flow is about all it will yield. (I visited the well in person.—Long.)

No. 81. The well is not far southeast from the Canadian River and is dug in a sandy loam with water in quicksand.

No. 91. Water in gravel.

No. 93. Water in sand.

No. 95. Abundance of water in quicksand.

No. 98. An abundance of water in sand. Used for irrigation.

No. 99. Water in sand rock. Is used for irrigation.

No. 101. Water was found in a clay formation.

No. 102. Water was found in gravel.

No. 103. Water found in red gravel.

No. 104. Water found just under a hard cap rock in sand.

No. 105. Water in gravel.

Nos. 106 and 107. Water was struck in rock.

No. 108. Water found in sand.

No. 109. Water in red kiel.

No. 110. Water was struck in rock.

No. 117. The well is in Oklahoma.

No. 122. Water in gravel.

No. 123. Water in gravel. It is used to irrigate garden.

No. 124. Water in gravel.

No. 125. Water in slate.

No. 126. Water in sand.

No. 127. Water in soapstone.

No. 128. Water in blue soapstone.
No. 129. Water in gray gypsum rock.
No. 130. Water in sand.
No. 131. Water in sand and gravel.
No. 151. Water analysis No. 48.
No. 152. Water in sandstone.
No. 153. This is a test well put down by a railroad company. Water found in sandstone.
No. 154. Water under sandrock. A strong flow.
No. 155. Water in sand.
No. 156. Water in iron-sandstone.
No. 157. Water in sandrock.
No. 158. Water in sand.
No. 159. Water in clay.
No. 160. Water in shelly sandstone. (Well in Lincoln, post-office in Payne County.)
No. 161. Water in gravel.
Nos. 162, 163, and 164. Water in sandstone.
No. 165. Water in sand.
No. 166. Water in clay.
No. 168. Water in soft sandstone.
No. 169. Water in gravel.
No. 170. Water in gravelly clay.
No. 171. Water in clay.
No. 175. The owner says it is like putting a pump into a river to try to pump it dry.
No. 176. Analysis No. 52.
No. 177. Water in soft red sandstone.
No. 178. Water in clay.
No. 179. Water in white sandstone.
No. 180. Water in clay.
No. 182. Water in clay and sand.
No. 183. Water in sandrock.
No. 184. Water in white sandstone.
No. 185. Water in sandrock.
Nos. 187, 188, 189, and 191. Water in sandstone.
Nos. 192 and 193. Water in sand.
Nos. 194 and 195. Water in sandrock.
No. 196. Water in white sand.
No. 197. Water in sand and gravel. The well will fill up in 30 minutes.
No. 198. Water in limestone.
No. 199. Water in flint.
No. 200. Water in blue clay.
No. 201. Water found in fine gravel.
No. 202. Water in sandstone. A fair supply.
No. 203. Water between gravel and soapstone.
No. 204. Water in clay.
No. 205. Water found in sandstone.
Nos. 206 and 207. Water in sandrock.
No. 208. Water in limestone.
No. 209. Water in sandrock; supply abundant, but no record of the flow.
Nos. 210 and 211. Water in gravel.
No. 216. Water contains traces of soda.
No. 218. Water in white sandstone.
Nos. 219 and 220. Water in sandstone.
No. 221. Water in sandrock.
No. 247. The well has since gone dry.

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WS 90. Geology and water resources of a part of the lower James River Valley, South Dakota, by J. E. Todd and C. M. Hall. 1904. 47 pp., 23 pls.

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WASHINGTON, D. C.

DECEMBER, 1905.

Water-Supply and Irrigation Paper No. 149. Series O, Underground Waters, 48

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

PRELIMINARY LIST

OF

DEEP BORINGS IN THE UNITED STATES

SECOND EDITION, WITH ADDITIONS

BY

N. H. DARTON

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1905

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., June 15, 1905.

SIR: I transmit herewith a preliminary list of deep borings in the United States (400 feet or more in depth), by Mr. N. H. Darton, and request that it be published in the series of Water-Supply and Irrigation Papers.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

PRELIMINARY LIST OF DEEP BORINGS IN THE UNITED STATES.

By N. H. Darton.

INTRODUCTION.

The first preliminary list of deep borings in the United States was issued as Water-Supply Papers Nos. 57 and 61. The present publication includes all of the wells listed in these two papers, together with many additional borings, mostly of recent date. Messrs. M. L. Fuller and A. C. Veatch, of the eastern section of hydrology, and other geologists of the Survey have contributed many new data. Descriptions of borings published in reports issued since 1901 have been incorporated as far as practicable. All the entries are by counties.

The wells and borings reported in the paper are all more than 400 feet in depth. The information concerning them has been obtained partly from replies to circular letters sent to all parts of the United States and partly from geological reports and other published sources. Owing to the difficulty of obtaining replies to the circulars, to lack of knowledge on the part of correspondents, and to the incompleteness of published records, doubtless there are borings which have not been reported. In regions of oil and gas wells, where borings are numerous, the individual wells can not be listed here, but representative wells are given. References to logs or records of the wells or extended descriptions of them are given in footnotes, and after the list of wells in each State there is added a list of the principal publications relating to deep borings in that State.

The bearing of the information given in the columns of the lists probably is apparent unless, perhaps, in the one headed "Height to which the water rises." In this column an entry such as "−45" indicates that the water rises to within 45 feet of the surface; "+45" indicates that it is a flowing well and has sufficient head to raise the water 45 feet above the surface in an open pipe 45 feet or more in height. The yield in gallons per minute usually is estimated. Depths and diameters often have been reported from memory and different sources of publication sometimes give different figures. Most wells which are not stated to be "for oil," "for gas," "brine," "abandoned,

etc., in the remarks column, or "not any" in the yield column, gen afford more or less water. Many of the gas and oil wells, acti abandoned, yield salt water.

ALABAMA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Baldwin County:					
Fort Morgan	700				
Barbour County:					
Eufaula	+400	4	5¼		
Do	950	6–4	6	− 50	
Harris	700				
Do	780	3		+ 15	Abandoned; milk at 140 feet to −1
Spring Hill	600			− 18	
Blount County:					
Oneonto	600				
Reeds Gap	1,930	6			
Bullock County:					
Bughall	920				Unsuccessful.
Fitzpatrick	900	6		− 30	
Do	1,300	6	12	− 30	
Union Springs	1,000		Many.		
Do	848¼	6–2¼	60		
Do	848¼	8	150	−240	
Do	569		Many.		Good water.
Do	750		Many.		Do.
Butler County:					
Greenville	+400	10–8	100	− 60	Two wells.
Calhoun County:					
Anniston	400–550	8	695	− 30	Several wells.
Do	568	6¼		− 4	
Do	480	10	1,200 to 1,900	− 80	
Choctaw County:					
Bladen Springs	1,300			+ 70	Water salt; first 200 feet, second 600 feet.
Butler	660			− 30	
Colbert County:					
Sheffield	1,550				
Coosa County:					
Hanover (?)	480	4		− 40	
Covington County:					
Andalusia	1,145				
Do	420				Water.
Crenshaw County:					
Brantley	600	4			Good flow; 2 wells
Cullman County:					
Cullman	700				City well.
Dallas County:					
Boguechitto	+400		0¼		In sec. 8, T. 18, R.
Do	460	6	75	+ 25	Temp., 68°.
Burton Hill	544				
Cahaba[1]	400				Temp., 73¾°.
Cahaba (on river)[1]	590	6	80	+ 22	Temp., 70°.
Cahaba (5 miles below)[1]	560		Each 250		2 wells.
Cahaba[1]	728		1,200		Temp., 77½°.
Do	744		1,200	−716	
Do	400, 555				
Hunters Field	550	5	70	+ 18	
Selma[2]	499		230		Temp., 67¾°.
Do	470	6			Temp., 72°.
Do	600	6	80	+ 16	Do.
Do	487	6	110	+ 28	Temp., 68°.
Do	650		100	+ 40	4 wells.
Do	425–500			Flow.	6 wells.
Do	500–700	5–6	10	+ 3	
Do	424–780	2½–6	10–110		
Tank Station	560	6	90	+ 35	Temp., 70°.
Fayette County:					
Fayette	500			− 30	
Franklin County:					
Russellville	1,400				2 miles east; unsu
Do	1,300				
Greene County:					
Boligee[1]	415			Flows.	Temp., 68°.
Do.[1]	420			Flows.	Temp., 66°.
Do.[1]	468			Flows.	Temp., 66½°.
Do.[1]	522			Flows.	Temp., 70°.

[1] Record, Am. Assoc. Adv. Science Proc., vol. 10, p. 95. [2] Ibid., pp. 97–98.

ALABAMA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Greene County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Boligee (at Finche's ferry).[1]	560			Flows.	Temp., 71°.
Do	500		40	+ 22	
Do	450	3	10	+ 10	
Burton Hill[1]	544				Temp., 70°.
Do.[1]	420				
Do.[1]	555				Temp., 75°.
Eutaw[1]	743			- 10	
Eutaw (10 miles southwest).[1]	440-550				Temp., 71°-72½°; 4 wells.
Eutaw	400-1,106	3-4			Several wells.
Do	420				
Forkland	575		20	+ 3	
Hairston	530		4	+ 2½	2½ miles east.
Steeles Bluff	400	3	22	+ 25	
Hale County:					
Akron	400	3		- 15	
Evansville Station	633	4		- 3	
Greensboro	400-800		Many.	- 30	Several wells; good water.
Do	1,600				
Greensboro (10 miles southwest).	450 or 860?	12	Many.		
Laneville	710			Flows.	Temp., 75°.
Do	719			Flows.	Temp., 76°.
Do	750			- 20	In progress.
Do	715		7,10		2 wells.
Do					
Lock No. 2	400	3	30		
Millwood	500	6	75		
Do	500	4½	75	+ 2	2 wells.
Moundville	600		1	- 1	
Do	480	3-1½	10	-1 to + 16	
Newbern	675		30	+ 4	
Do	410-500	One, 3	3-35	One flows.	5 wells.
Powers	406	3	7½	+ 25	
Sawyerville	440-640	3	[1]17	-8 to - 10	4 wells.
Stewart	600			+ 8	
Do	400-620	3	6,8	- 39 to +35	
Henry County:					
Dothan	625	8		-150	
Houston County:					
Columbia	485	8-6	50	- 8	
Dothan	625	8			
Do	625	8-6	50	-150	
Jackson County:					
Carpenter	400				Unsuccessful.
Larkinsville	400				Do.
Jefferson County:					
Birmingham	550		70	30	
Lauderdale County:					
Florence	+400				For gas; unsuccessful.
Lawrence County:					
Jennings (3 miles southeast).[2]	5,120	6			Gas, oil, and salt water.
Jennings	2,120	6			
Town Creek[3]	515				Abandoned.
Macon County:					
Armstrong	442				Good water.
Fort Davis	422	4		- 62	
Roba	450				Good water supply.
Tuskegee	500	6			Unsuccessful.
Do	760	8			Do.
Madison County:					
Hazlegreen	954				For oil; unsuccessful; yields some gas.
Newmarket[4]	965	2		Flows.	
Marengo County:					
Demopolis	765	3	30	+ 20	Temp., 64°.
Do	735	4	15	+ 12	
Do	850	6½	60	Flows.	
Do	800	3	Many.	+ 52	
Demopolis (3 miles south).	1,350		Many.	- 30	
Demopolis (4 miles northeast).	500		200	Flow.	Several wells.
Faunsdale	700		8	+ 2½	
Do	450-830				5 wells.

[1] Record, Am. Assoc. Adv. Science Proc., vol. 10, p. 95.
[2] Ala. Geol. Surv. Rept. Valley Regions, part 1, pp. 61-62.
[3] Record, Pa. 2d Geol. Surv. Rept. II, p. 283.
[4] Record, Ala. Geol. Surv. Rept. Valley Regions, part 1, p. 127.

ALABAMA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Marengo County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Linden	1,193		1	Flows.	Water at 1,040 to 1,115 feet.
Do	1,200	1¼	20	Flows.	
Marshall County:					
Guntersville	1,006	8-6			Temp., 60°.
Mobile County:					
Fort Gaines	919	6			
Mobile	700	6	400		Temp., 76°.
Do	735		Many.	+ 90	Temp., 78°.
Do	800	6	500		Temp., 76°.
Do	800	6	1,000	+ 70	Temp., 78°.
Do	850				
Do.[1]	1,556				
Do	1,526				
St. Elmo	550				
Montgomery County:					
Montgomery	650-450	6	974-200	− 60	4 wells; originally flowed to +20 feet.
Do	448-1,091		60-130	−45 to +6	Several wells.
Sprague Junction	400	8-6		− 75	
Morgan County:					
Hartsell[2]	1,730	2			1 mile north of town; salt water at 352 and 1,730 feet; gas at 602 and 1,094 feet; sulphur water at 160 feet.
Perry County:					
Uniontown	895	8		−125	
Do	1,195	8	300	−120	Water from 870 feet.
Do	1,085			−200	
Uniontown (10 miles south).	875	4-3	10	− 40	Water at 775 feet.
Pickens County:					
Dancey	450-903	One 2	One 3¼	−22 to +20	
Sherman	600-725	4	6¼-30		3 wells.
Pike County:					
Troy	2,700				Unsuccessful.
Do	2,632		75		
Do	350-650				
Hannon	480	4		− 40	
Russell County:					
Hatchechubbee	420		8	No flow	Small supply of water at 250 feet.
Hurtsboro	530	4		− 9	
Do	530	4	+ 10	− 9	
Do	550	3	+ 11	− 9	
Do	565	3	+ 12	− 23	
Do	526	3		− 8	
Oswichee	465		12		
Pittsboro	445				
Seale	400	4		− 75	
Sumter County:					
Epes	700		3	+ 1¼	
Do	500-930	2-5	1-28	−24 to +30	Many wells.
Livingston	1,010 1,062				2 wells.
Warsaw	400-702	2-4	1-5¼	−30 to +40	Several wells.
Tuscaloosa County:					
Holton	544		50		
Tuscaloosa	520	6		− 14	
Williffords Landing (Sylvan post-office).	400?				
Sledges	490	4	Many.	− 60	

[1] Science, vol. 16, p. 836, Nov. 21, 1902.
[2] Ala. Geol. Surv. Rept. Valley Regions, part 1, pp. 62-63

LIST OF PUBLICATIONS RELATING TO DEEP BORINGS IN ALABAMA.

Report on Valley Regions, Alabama Geological Survey, part 1.
American Association for the Advancement of Science Proceedings, vol. 10.
Science, vol. 16, Nov., 1902.

ARIZONA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Graham County:					
Pima	220				Unsuccesful.
Safford	500			No flow.	
Thatcher	430		Few.	No flow.	
Maricopa County:					
Gila Bend	1,300			−700	
Phoenix	750	5		− 20	Abandoned.
Do	475				
Do	1,420				
Do	1,475				
Phoenix (12 miles west)	500				Not completed.
Sentinel	1,029	5	50	−185	
Wickenburg, northwest of.	400				No good results.
Mohave County:					
Drake	488	10			In progress.
Haviland	600	10	Many.		
Kingman	900 1,100		No water.		60 miles north.
Sulphur Springs Valley[1]	765				
Yucca	534			−325	Satisfactory water supply
Navajo County:					
Winslow	1,700				No fresh water.
Pinal County:					
Florence	413	6	Few.		Well never used.
Yavapai County:					
Ash Fork	1,025	10	No water.		In volcanic rock.
Aubrey	936	12–8	No water.		
Yuma County:					
Mohawk	1,100	5¼–4¼			3 wells.
Do	500		28		

[1] Record, Am. Philos. Soc. Proc., vol. 40, No. 167, pp. 161–164, 1902.

PUBLICATIONS RELATING TO DEEP BORINGS IN ARIZONA.

American Philosophical Society Proceedings, vol. 40, No. 167., pp. 161–164, 1902.

ARKANSAS.

Location.	Depth.	Diameter.	Yield per minute.	Depth to water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Ashley County:					
Crossett	976			− 74 − 36 − 80	Fresh water 80–110 feet. Sulphur water 450 feet. Salt water 975 feet.
Do	450				Abandoned.
Portland	400			− 30	Alkaline.
Benton County:					
Gentry	492	8–6¼	420	− 19	
Do	+ 700			No flow.	
Do	1,000	7		− 30	Water at 700 and 900 feet.
Do	+1,350				
Bradley County:					
Warren (1 mile east)	648	2¼	100	− 36	
Chicot County:					
Dermott	750	4–2¼		− 11	Water from sand at about 600 feet, pumps 75 gallons per minute.
Clark County:					
Arkadelphia (1 mile east).	551			Flow.	Strong flow of salt water at 450, rock at 551 feet.
Arkadelphia (2 miles east).	410	6–4	Large.	+ 26	Salt water.
Gurdon	760	10–6			Oil well; abandoned artesian water at 198 feet; salt water at about 600 feet.
Gurdon (4 miles south of, at Old Empire mill).	402	3¼		− 60	
Okolona (3 miles southeast).	400			− 30	Hard water.
Cleveland County:					
Anderson	432	2¼	42	− 32	
Kedron (1 mile west, at Kendall's mills)	457	3	Large.	− 50	Sulphur water.
Rison	700				No water.

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ARKANSAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Rema
Phillips County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Helena	500	12-6	10	−30	
Do	543	8	656	−30	
Pike County:					
Pike City (5 miles south)	1,400	.....	Small.	Flow.	Oil well; uns
Bowen	400	.....	Many.	No flow.	Several wells in the coun
Polk County:					
Mena	1,615	.....	.....	−20	Abundant s posed as su waterworks
Do	+700	10	Many.	No flow.	
Pope County:					
Russellville (railroad well).	1,006	12-10	.....	.....	Abandoned; at 90 feet.
Randolph County:					
Pocahontas	650	6	.....	.....	In progress.
St. Francis County:					
Forrest City	465	4	Many.	.....	
Do	460	6	.....	−160	
Sebastian County:					
Huntington	501	5¼	20	− 25	
Sevier County:					
Ben Lomond (1 mile south).	400	.....	.....	− 6	Water struck
Ben Lomond (¼ mile south).	540	3	.....	−125	
White Cliffs	460	.....	.....	+ 25	
Do	450	.....	.....	+ 8	Temp., 65°.
Do	540	.....	.....	− 60	Temp., 64°.
Washington County:					
Fayetteville[1]	1,480	.....	.....	.....	

[1] Record, Ark. Geol. Surv. Rept., vol. 2, 1891, pp. 67–69.

LIST OF PUBLICATIONS RELATING TO DEEP BORINC ARKANSAS.

Arkansas Geol. Surv. Report, vol. 1, 1891.

Geology and water resources of northern Louisiana and southern Arl A. C. Veatch: Prof. Paper U. S. Geol. Survey No. 46. (In preparation.)

CALIFORNIA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Rema
Alameda County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Alameda	489	.....	.....	Surface.	
Do.[1]	409	.....	.....	8	
Centerville	442	.....	.....	Flows.	
Fitchburg[2]	400–500	7-12	1,000	No flow.	Several wells
Irvington	450	.....	.....	Flows.	
Oakland	506	.....	112	Flows.	
Ontaria	457	9¼	.....	No flow.	
Butte County:					
Chico	686	.....	Several.	No flow.	
Oroville	800	3	4	lows.?	
Fresno County:					
Coalinga[3]	400–650	.....	.....	.....	Numerous oil groups; one the other 9
Fresno	575	.....	.....	.....	
J. G. James's ranch	600–800	7-8	Flows.	+ 3	Several wells.
Kingsburg	600	.....	.....	No flow.	
Glenn County:					
Norman (2 miles north)[4]	940	2	4	+15	Small amour 337 feet.
Norman (about ¼ mile southeast).	1,100	.....	.....	Surface.	Small amour 500 feet.
Inyo County:					
Bishop	420	.....	.....	.....	In progress.

[1] Record, Cal. State Mining Bureau, 11th Rept., 1891–92, pp. 135–136.
[2] Ibid., p. 134.
[3] Analysis, ibid., 12th Rept., 1893–94
[4] Record, ibid., 11th Rept., 1891–92.

CALIFORNIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Kern County:					
Bakersfield	480	8	30	Flows.	
Do	500	8	300	Flows.	
Do	1,100		480	Flows.	
Do	600	8	30	Flows.	
Do	400	8	1,500	Flows.	
Buenavista	410				Oil at 3[illegible]2 feet.
Delano	713	15	3,470	Flows.	
Delano (5 miles southwest).	822			— 3	
Delano (18 miles west)	828	11-7	1,077		Water strata between 484 feet and bottom of well; sulphur and other minerals.
Miramonte	636	8	1,670	Flows.	
Do	457	8			
Semitropic	495	8-7	Many.	Flows.	
Smyrna Colony	524-600				2 wells.
Sunset District[1]	500-1,350				Numerous oil and brine wells.
Kings County:					
Hanford[2]	500-800	9-7	100-400	Flow.	Numerous wells.
Do	1,300				
Lassen County:					
Bieber	740	4			
Susanville	960			—10	
Los Angeles County:					
Alhambra	400	7			Oil well.
Clearwater (?)	465		Many.		
Downey	412	2	60		
Garvanza (west of)	985				For oil; unsuccessful.
Glendora	2,038	5¼		No flow.	
Long Beach	500	8	1,100	Flows.	
Do	460	9-7	Many.	Flows.	
Los Angeles[3]	450-1,300				Numerous oil wells; some abandoned.
Los Angeles (The Ivanhoe).[3]	+1,000				Small supply of oil; abandoned.
Los Angeles (United States Hotel).[3]	+ 900				Gas at 900 feet.
Los Angeles (Stewart and McFarland).[4]	1,485				For oil; unsuccessful.
Los Angeles (Angelina Heights).[3]	1,186				For oil or gas; abandoned.
Los Angeles (Boyle Heights).	600				For oil; unsuccessful.
Los Angeles (Dr. Long's ranch).	500	7			Small supply of oil; abandoned.
Los Angeles (Lookout Mountain).	550				Do.
Los Angeles (few miles southeast).					Gas well.
Los Angeles (4 miles northwest).[5]	820				Small supply of oil.
Los Angeles (5¼ miles west).[3]	+ 500				Small flow of gas; abandoned.
Los Angeles (6 miles west).[3]	658-1,485				Two wells, for oil; unsuccessful.
Los Angeles (10 miles north of west).[4]	520				Two wells, sulphur water and some gas; abandoned.
Norwalk	480	4			
Pasadena	1,200				No water.
Pico	600-735				Numerous oil wells.
Puente[6]	100-1,750				Do.
San Gabriel	+ 500	7			
Madera County:					
Madera[7]	1,200			— 3	
Do	680			— $\frac{1}{10}$	
Madera (6 miles west)	633	7	¼	Flows.	
Mendocino County:					
Potter Valley	400			— 11	
Merced County:					
Atwater	400	7	5		
Dos Palos	442-550				Several wells.

[1] Cal. State Mining Bureau, 12th Rept., 1893-94, pp. 353-354; record, Cal. State Mining Bureau Bull. No. 3, Gas and Petroleum Yielding Formations, Central Valley, p. 30.

[2] Ibid., 11th Rept., 1891-92, p. 489.

[3] Ibid., Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 14-17.

[4] Ibid., 7th Rept., 1887, p. 78.

[5] Ibid., p. 77.

[6] Ibid., Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 18-21.

[7] Ibid., 11th Rept., 1891-92, p. 211.

etc., in the remarks column, or "not any" in the yield column, gener afford more or less water. Many of the gas and oil wells, active abandoned, yield salt water.

ALABAMA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Baldwin County:					
Fort Morgan	700				
Barbour County:					
Eufaula	+400	4	5½		
Do	950	6–4	6	− 50	
Harris	700				
Do	780	3		+ 15	Abandoned; milky at 140 feet to −15 f
Spring Hill	600			− 18	
Blount County:					
Oneonto	600				
Reeds Gap	1,930	6			
Bullock County:					
Bughall	920				Unsuccessful.
Fitzpatrick	900	6		− 30	
Do	1,300	6	12	− 30	
Union Springs	1,000		Many.		
Do	848½	6–2½	60		
Do	848½	8	150	−240	
Do	569		Many.		Good water.
Do	750		Many.		Do.
Butler County:					
Greenville	+400	10–8	100	− 60	Two wells.
Calhoun County:					
Anniston	400–550	8	695	− 30	Several wells.
Do	558	6½		− 4	
Do	480	10	1,200 to 1,900	− 80	
Choctaw County:					
Bladen Springs	1,300			+ 70	Water salt; first fl 200 feet, second f 600 feet.
Butler	660			− 30	
Colbert County:					
Sheffield	1,550				
Coosa County:					
Hanover (?)	480	4		− 40	
Covington County:					
Andalusia	1,145				
Do	420				Water.
Crenshaw County:					
Brantley	600	4			Good flow; 2 wells.
Cullman County:					
Cullman	700				City well.
Dallas County:					
Boguechitto	+400		0½		In sec. 8, T. 18, R. 8
Do	460	6	75	+ 25	Temp., 68°.
Burton Hill	544				
Cahaba[1]	400				Temp., 73½°.
Cahaba (on river)[1]	590	6	80	+ 22	Temp., 70°.
Cahaba (5 miles below)[1]	560		Each 250		2 wells.
Cahaba[1]	728		1,200		Temp., 77½°.
Do	744		1,200	−716	
Do	400, 555				
Hunters Field	550	5	70	+ 18	
Selma[2]	499		230		Temp., 67½°.
Do	470	6			Temp., 72°.
Do	600	6	80	+ 16	Do.
Do	487	6	110	+ 28	Temp., 68°.
Do	650		100	+ 40	4 wells.
Do	425–500			Flow.	6 wells.
Do	500–700	5–6	10	+ 3	
Do	421–780	2½–6	10–110		
Tank Station	560	6	90	+ 35	Temp., 70°.
Fayette County:					
Fayette	500			− 30	
Franklin County:					
Russellville	1,400				2 miles east; unsucc
Do	1,300				
Greene County:					
Boligee[1]	415			Flows.	Temp., 68°.
Do.[1]	420			Flows.	Temp., 66°.
Do.[1]	468			Flows.	Temp., 66½°.
Do.[1]	522			Flows.	Temp., 70°.

[1] Record, Am. Assoc. Adv. Science Proc., vol. 10, p. 95. [2] Ibid., pp. 97–98.

ALABAMA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Greene County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Boligee (at Finche's ferry).[1]	560			Flows.	Temp., 71°.
Do	500		40	+ 22	
Do	450	3	10	+ 10	
Burton Hill[1]	544				Temp., 70°.
Do.[1]	420				
Do.[1]	555				Temp., 75°.
Eutaw[1]	743			− 10	
Eutaw (10 miles southwest).[1]	440–550				Temp., 71°–72½°; 4 wells.
Eutaw	400–1,106	3–4			Several wells.
Do	420				
Forkland	575		20	+ 3	
Hairston	580		4	+ 2½	2½ miles east.
Steeles Bluff	400	3	22	+ 25	
Hale County:					
Akron	400	3		− 15	
Evansville Station	633	4		− 3	
Greensboro	400–800		Many.	− 30	Several wells; good water.
Do	1,600				
Greensboro (10 miles southwest).	450 or 850?	12	Many.		
Laneville	710			Flows.	Temp., 75°.
Do	719			Flows.	Temp., 76°.
Do	750			- 20	In progress.
Do	715		7,10		2 wells.
Do					
Lock No. 2	400	3	30		
Millwood	500	6	75		
Do	500	4½	75	+ 2	2 wells.
Moundville	600		1	-- 1	
Do	480	3–1½	10	−1 to + 16	
Newbern	475		30	+ 4	
Do	410–500	One, 3	3–35	One flows.	5 wells.
Powers	406	3	7½	+ 25	
Sawyerville	440–640	3	[1]17	−8 to − 10	4 wells.
Stewart	600			+ 8	
Do	400–620	3	6,8	−39 to +35	
Henry County:					
Dothan	625	8		−150	
Houston County:					
Columbia	485	8–6	50	− 8	
Dothan	625	8			
Do	625	8–6	50	−150	
Jackson County:					
Carpenter	400				Unsuccessful.
Larkinsville	400				Do.
Jefferson County:					
Birmingham	550		70	30	
Lauderdale County:					
Florence	+400				For gas; unsuccessful.
Lawrence County:					
Jennings (3 miles southeast).[2]	5,120	6			Gas, oil, and salt water.
Jennings	2,120	6			
Town Creek[3]	515				Abandoned.
Macon County:					
Armstrong	412				Good water.
Fort Davis	422	4		62	
Roba	450				Good water supply.
Tuskegee	500	6			Unsuccessful.
Do	760	8			Do.
Madison County:					
Hazlegreen	954				For oil; unsuccessful; yields some gas.
Newmarket[4]	965	2		Flows.	
Marengo County:					
Demopolis	765	3	30	+ 20	Temp., 64°.
Do	735	4	15	+ 12	
Do	830	6½	60	Flows.	
Do	800	3	Many.	+ 52	
Demopolis (3 miles south).	1,350		Many.	- 30	
Demopolis (4 miles northeast).	500		200	Flow.	Several wells.
Faunsdale	700		8	+ 2½	
Do	450–830				5 wells.

[1] Record, Am. Assoc. Adv. Science Proc., vol. 10, p. 95.
[2] Ala. Geol. Surv. Rept. Valley Regions, part 1, pp. 61–62.
[3] Record, Pa. 2d Geol. Surv. Rept. II, p. 283.
[4] Record, Ala. Geol. Surv. Rept. Valley Regions, part 1, p. 127.

ALABAMA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Marengo County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Linden	1,193	.....	1	Flows.	Water at 1,040 to feet.
Do	1,200	1¼	20	Flows.	
Marshall County:					
Guntersville	1,006	8-6	.....	.....	Temp., 60°.
Mobile County:					
Fort Gaines	919	6	.....	.....	
Mobile	700	6	400	.....	Temp., 76°.
Do	735	.....	Many.	+ 90	Temp., 78°.
Do	800	6	500	.....	Temp., 76°.
Do	800	6	1,000	+ 70	Temp., 78°.
Do	850	.....	.....	.....	
Do.[1]	1,556	.....	.....	.....	
Do	1,526	.....	.....	.....	
St. Elmo	550	.....	.....	.....	
Montgomery County:					
Montgomery	650-450	6	974-200	− 60	4 wells; originally fl to +20 feet.
Do	448-1,091	.....	60-130	−45 to +6	Several wells.
Sprague Junction	400	8-6	.....	− 75	
Morgan County:					
Hartsell[2]	1,730	2	.....	.....	1 mile north of town water at 352 and feet; gas at 602 and feet; sulphur wat 160 feet.
Perry County:					
Uniontown	895	8	.....	−125	
Do	1,195	8	300	−120	Water from 870 feet.
Do	1,085	.....	.....	−200	
Uniontown (10 miles south).	875	4-3	10	− 40	Water at 775 feet.
Pickens County:					
Dancey	450-903	One 2	One 3¼	−22 to +20	
Sherman	600-725	4	6¼-30	.....	3 wells.
Pike County:					
Troy	2,700	.....	.....	.....	Unsuccessful.
Do	2,632	.....	75	.....	
Do	350-650	.....	.....	.....	
Hannon	480	4	.....	− 40	
Russell County:					
Hatchechubbee	420	.....	8	No flow	Small supply of wat 250 feet.
Hurtsboro	530	4	.....	− 9	
Do	530	4	+ 10	− 9	
Do	550	3	+ 11	− 9	
Do	565	3	+ 12	− 23	
Do	526	3	.....	− 8	
Oswichee	465	.....	12	.....	
Pittsboro	445	.....	.....	.....	
Seale	400	4	.....	− 75	
Sumter County:					
Epes	700	.....	3	+ 14	
Do	500-930	2-5	1-28	24 to +30	Many wells.
Livingston	1,010 1,062	.....	.....	.....	2 wells.
Warsaw	400-702	2-4	1-5¼	30 to +40	Several wells.
Tuscaloosa County:					
Tolton	544	.....	50	.....	
Tuscaloosa	520	6	.....	− 14	
W H fords Landing (Sylvan post-office).	400?	.....	.....	.....	
Sledges	490	4	Many.	− 60	

[1] Science, vol. 16, p. 836, Nov. 21, 1902.
[2] Ala. Geol. Surv. Rept. Valley Regions, part 1, pp. 62-63

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Science, vol. 16, Nov., 1902.

ARIZONA.

›n.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
.....	420	.....	.....	.....	Unsuccesful.
.....	500	.....	.....	No flow.	
.....	430	.....	Few.	No flow.	
y:					
.....	1,300	.....	.....	−700	
.....	750	5	.....	− 20	Abandoned.
.....	475	.....	.....	.....	
.....	1,420	.....	.....	.....	
.....	1,475	.....	.....	.....	
miles west)	500	.....	.....	.....	Not completed.
.....	1,029	5	50	−185	
, northwest	400	.....	.....	.....	No good results.
.....	488	10	.....	.....	In progress.
.....	600	10	Many.	.....	
.....	900 1,100	.....	No water.	.....	60 miles north.
ngs Valley[1].	765	.....	.....	.....	
.....	634	.....	.....	−325	Satisfactory water supply
.....	1,700	.....	.....	.....	No fresh water.
.....	413	6	Few.	.....	Well never used,
.....	1,025	10	No water.	.....	In volcanic rock.
.....	936	12–8	No water.	.....	
.....	1,100	5¼–4½	.....	.....	3 wells.
.....	500	.....	28	.....	

[1] Record, Am. Philos. Soc. Proc., vol. 40, No. 167, pp. 161–164, 1902.

ATIONS RELATING TO DEEP BORINGS IN ARIZONA.

'hilosophical Society Proceedings, vol. 40, No. 167., pp. 161–164, 1902.

ARKANSAS.

›n.	Depth.	Diameter.	Yield per minute.	Depth to water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
.....	976	.....	.....	− 74 − 36 − 80	Fresh water 80–110 feet. Sulphur water 450 feet. Salt water 975 feet.
.....	450	.....	.....	.....	Abandoned.
.....	400	.....	.....	− 30	Alkaline.
.....	492	8–6½	420	− 19	
.....	700	.....	.....	No flow.	
.....	1,000	7	.....	− 30	Water at 700 and 900 feet.
.....	1,350	.....	.....	.....	
ile east)	648	2½	100	− 36	
.....	750	4–2½	.....	− 11	Water from sand at about 600 feet, pumps 75 gallons per minute.
ı (1 mile	551	.....	.....	Flow.	Strong flow of salt water at 450, rock at 551 feet.
ı (2 miles	410	6–4	Large.	+ 26	Salt water.
.....	760	10–6	.....	.....	Oil well; abandoned artesian water at 198 feet; salt water at about 600 feet.
miles south					
Empire mill).	402	3½	.....	− 60	
miles south-	400	.....	.....	− 30	Hard water.
ty:					
.....	632	2½	42	− 32	
ile west, at mills).....	457	3	Large.	− 50	Sulphur water.
.....	700	.....	.....	.....	No water.

ARKANSAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remark
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Columbia County:					
Waldo	1,038	5–4	.....	.....	Abandoned. S at 540 feet, ro feet.
Craighead County:					
Jonesboro (waterworks)	+600	.....	.....	.....	
Jonesboro	1,298	8–6	Many.	− 35	
Crittenden County:					
Turrell	860	6–4	Many.	− 10	
Dallas County:					
Fordyce	502	4	60	− 70	Temp., 72.5°.
Desha County:					
Arkansas City	552	6	65	− 12	Temp., 72°.
Drew County:					
Blissville	490	10–4	.....	− 11	Water at 30, 80 and 490 feet.
Monticello (cotton mill)	810	6–2¼	52	−144	
Monticello (city well)	750	8	110	−126	Temp., 78°.
Monticello (ice works)	800	2¼	.....	−145	
Monticello	500	8	.....	−125	
Do	604	8–4¼	100	−110	
Wilmer	455	4–2¼	380	− 2	Temp., 72°; pun
Do	800	1	.....	Flows.	Water at 184, 31 800 feet.
Do	400	.....	.....	.....	
Garland County:					
Hot Springs	860	6	13	.....	
Hempstead County:					
Columbus	730	3	.....	.....	No water.
Fulton	700	2	.....	Flows.	Good water; w because it was
Fulton (3¼ miles south, at Moore place).	480	2	.....	Flows.	
Fulton (4¼ miles south, at Smith place).	480	.....	.....	Flows.	
Fulton (7 miles south, at Ferguson place).	655	4	.....	Flows.	Caved in and al
Do	755	.....	.....	.....	No water.
Guernsey (railroad well)	460	6	58	0	Water first stru feet.
Guernsey (1¼ miles south)	434	2	.....	+ 18	
Guernsey (1¼ miles southeast).	427	2	.....	+ 6	
Hope (city well)	950	5–4	.....	.....	Water 375 to 44 water below; ed.
Hope	404	2	.....	− 70?	
Hope (waterworks)	500	9–6	150	− 66	
Hope (ice factory)	428	4	.....	− 58	
Hope (oil mill)	426	3	.....	− 62	
Hope	400	4	.....	− 47	
Hope (5 miles southeast)	580	.....	.....	.....	Abandoned.
Hope	400	4	.....	− 2	
Do	410	.....	.....	30	
Do	406	.....	.....	15	
Do	420	.....	.....	18	
Do	427	.....	.....	26	
Springhill (1 mile north)	580	2	Large.	30	
Springhill (1¼ miles northwest).	555	2	Large.	20	
Springhill	500	2	.....	+ 25	
Springhill (2 miles northwest).	434	4	.....	Flows.	
Springhill	541	2	.....	− 16	
Do	408–498	2	.....	−37 to +18	5 wells.
Washington	750	3	.....	.....	No water.
Yancy	700	.....	.....	.....	Do.
Hot Spring County:					
Malvern	478	.....	50	.....	
Howard County:					
Allbrook (1 mile east)	430	2	6	+ 17	
Allbrook (1 mile north)	500	3	.....	− 18	
Allbrook (2¼ miles north)	480	3	.....	− 80	Water first enco 380 feet.
Allbrook (2 miles west)	466	3	.....	Flows.	
Allbrook	400–496	2–3	.....	−22 to +17	Several wells.
Buckrange, center point (2 miles south).	500	2	.....	− 98	
Saline Landing[1]	466	.....	.....	.....	
Saratoga	600	3	.....	No flow.	Supplies gin.
Do	440	3	.....	.....	

[1] Record, Ark. Geol. Surv. Rept., vol. 1, 1891, p. 105.

ARKANSAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Howard County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Saratoga (3 miles east)	788	3½-2	.....	−50	
Saratoga (4 miles west, at Saline Landing).	455	2½	1	+12	Brackish.
Saratoga	465	.....	.....	−16	
Tollette	460	3	.....	−30	
Independence County:					
Cushman	2,040	5	10	.....	
Jackson County:					
Newport (1 mile southwest).	1,000	8	Many.	−20	
Jefferson County:					
Pine Bluff (waterworks)	905 915	8-6	700	−31	2 wells.
Pine Bluff (railroad)	+890	8	650	−22	Temp., 64°.
Pine Bluff (Sawyer-Austin Lumber Co).	915	8	.....	−47	
Pine Bluff	840	10-5½	185	−20	
Redfield	545	6	20	−60	
Johnson County:					
Clarksville	500	6	.....	−15	
Lafayette County:					
Frostsville	464	6	.....	−36 −54	Water at 112 to 120 and 140 to 160 feet. Water at 464 feet; sulphur water.
New Lewisville (2 miles west, at Kelly station).	502	.....	.....	−30	Water at 204 and at 468 to 480 feet; lower water strong with H_2S.
Stamps	415	8	175	Flows.	Water 233 to 345 feet; sulphur water at 415 feet; pumped.
Little River County:					
Hudson	830	4	.....	−40	Water hard.
Do	900	.....	.....	.....	
Do	800	4	Many.	No flow.	
Rocky Comfort (1 mile south).	700-800	.....	.....	.....	No water.
Rocky Comfort (3½ miles southwest).	500	4-2	.....	−30	Do.
Rocky Comfort (10 miles south).	560	2	.....	.....	Do.
White Cliffs	460	.....	.....	+25	
Do	450	.....	.....	+ 8	Temp., 65°.
Do	540	.....	.....	− 60	Temp., 64°.
White Cliffs (1 mile north).	400	.....	.....	Flows.	
White Cliffs (1 mile south).	400	.....	.....	Flows.	Salty.
White Cliffs	535	3	.....	Flows.	
Logan County:					
Magazine	1,800	.....	.....	.....	
Madison County:					
Mante	840	6	.....	Flows.	
Miller County:					
Homan (4 miles northeast).	486	.....	.....	Slight flow.	2 wells.
Homan (4 miles east)	492	.....	.....	Flows.	
Homan (2 miles west)	408	2	.....	− 8	Brackish water.
Texarkana (waterworks)	930	12-6	190	−28	Do.
Texarkana (1½ miles east)	1,350	12-6	.....	30	Oil wells; unsuccessful.
Texarkana (16 miles east, at Dooley's ferry).	700	.....	.....	.....	Abandoned.
Nevada County:					
Emmet (4 miles south)	416	3	10	Flows.	
Emmet (5 miles south)	428	.....	.....	− 6	
Emmet (5 miles southeast).	419	2	2	+13	Many flowing wells in this region.
Emmet (4½ miles southeast).	400	2	.....	+17	
Emmet (6 miles southeast).	475	3	.....	−17	
Laneburg (½ mile north)	568	3	+10	− 4	
Laneburg (2 miles north)	465	3	2	+11	
Laneburg (1 mile north)	520	2	.....	−32	
Laneburg (2½ miles west)	456	2	.....	0	
Do	436	2	2	+ 5	
Laneburg	419-542	.....	.....	.....	Several wells.
Verde	400-570	2-3	.....	−44 to −17	Do.
Ouachita County:					
Bearden (1 mile east, at Best).	1,001	6	200	−40	Water salty and alkaline.
Millville	470	.....	.....	−45	Abandoned; too much quicksand.

ARKANSAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks
Phillips County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Helena	500	12-6	10	−30	
Do	543	8	656	−30	
Pike County:					
Pike City (5 miles south)	1,400	.....	Small.	Flow.	Oil well; unsucc
Bowen	400	.....	Many.	No flow.	Several wells of in the county.
Polk County:					
Mena	1,615	.....	.....	−20	Abundant supp posed as suppl waterworks.
Do	+700	10	Many.	No flow.	
Pope County:					
Russellville (railroad well).	1,006	12-10	.....	.....	Abandoned; a li at 90 feet.
Randolph County:					
Pocahontas	650	6	.....	.....	In progress.
St. Francis County:					
Forrest City	465	4	Many.	.....	
Do	460	6	.....	−160	
Sebastian County:					
Huntington	501	5¼	20	− 25	
Sevier County:					
Ben Lomond (1 mile south).	400	.....	.....	− 6	Water struck at
Ben Lomond (¼ mile south).	540	3	.....	−125	
White Cliffs	460	.....	.....	+ 25	
Do	450	.....	.....	+ 8	Temp., 65°.
Do	540	.....	.....	− 60	Temp., 64°.
Washington County:					
Fayetteville[1]	1,480	.....	.....	.....	

[1] Record, Ark. Geol. Surv. Rept., vol. 2, 1891, pp. 67-69.

LIST OF PUBLICATIONS RELATING TO DEEP BORINGS ARKANSAS.

Arkansas Geol. Surv. Report, vol. 1, 1891.

Geology and water resources of northern Louisiana and southern Arkar A. C. Veatch: Prof. Paper U. S. Geol. Survey No. 46. (In preparation.)

CALIFORNIA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks
Alameda County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Alameda	489	.....	.....	Surface.	
Do.[1]	409	.....	.....	8	
Centerville	442	.....	.....	Flows.	
Fitchburg[2]	400-500	7-12	1,000	No flow.	Several wells.
Irvington	450	.....	.....	Flows.	
Oakland	506	.....	112	Flows.	
Ontaria	457	9¼	.....	No flow.	
Butte County:					
Chico	686	.....	Several.	No flow.	
Oroville	800	3	4	lows.?	
Fresno County:					
Coalinga[3]	400-650	.....	.....	.....	Numerous oil we groups; one 3 m the other 9 mil
Fresno	575	.....	.....	.....	
J. G. James's ranch	600-800	7-8	Flows.	+ 3	Several wells. T
Kingsburg	600	.....	.....	No flow.	
Glenn County:					
Norman (2 miles north)[4]	940	2	4	+15	Small amount 337 feet.
Norman (about ¼ mile southeast).	1,100	.....	.....	Surface.	Small amount 500 feet.
Inyo County:					
Bishop	420	.....	.....	.....	In progress.

[1] Record, Cal. State Mining Bureau, 11th Rept., 1891-92, pp. 135-136.
[2] Ibid., p. 134.
[3] Analysis, ibid., 12th Rept., 1893-94, pp
[4] Record, ibid., 11th Rept., 1891-92, p.

CALIFORNIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Kern County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Bakersfield	480	8	30	Flows.	
Do	500	8	300	Flows.	
Do	1,100		480	Flows.	
Do	600	8	30	Flows.	
Do	400	8	1,500	Flows.	
Buenavista	410				Oil at 3½ feet.
Delano	713	15	3,470	Flows.	
Delano (5 miles southwest).	822			— 3	
Delano (18 miles west)	828	11-7	1,077		Water strata between 484 feet and bottom of well; sulphur and other minerals.
Miramonte	636	8	1,670	Flows.	
Do	457	8			
Semitropic	495	8-7	Many.	Flows.	
Smyrna Colony	524-600				2 wells.
Sunset District[1]	500-1,350				Numerous oil and brine wells.
Kings County:					
Hanford[2]	500-800	9-7	100-400	Flow.	Numerous wells.
Do	1,300				
Madera County:					
Bieber	740	4			
Susanville	960			—10	
Los Angeles County:					
Alhambra	400	7			Oil well.
Clearwater (?)	465		Many.		
Downey	412	2	60		
Garvanza (west of)	985				For oil; unsuccessful.
Glendora	2,038	5½		No flow.	
Long Beach	500	8	1,100	Flows.	
Do	460	9-7	Many.	Flows.	
Los Angeles[3]	450-1,300				Numerous oil wells; some abandoned.
Los Angeles (The Ivanhoe).[3]	+1,000				Small supply of oil; abandoned.
Los Angeles (United States Hotel).[3]	+ 900				Gas at 900 feet.
Los Angeles (Stewart and McFarland).[4]	1,485				For oil; unsuccessful.
Los Angeles (Angelina Heights).[3]	1,186				For oil or gas; abandoned.
Los Angeles (Boyle Heights).	600				For oil; unsuccessful.
Los Angeles (Dr. Long's ranch).	500	7			Small supply of oil; abandoned.
Los Angeles (Lookout Mountain).	550				Do.
Los Angeles (few miles southeast).					Gas well.
Los Angeles (4 miles northwest).[5]	820				Small supply of oil.
Los Angeles (5¼ miles west).[3]	+ 500				Small flow of gas; abandoned.
Los Angeles (6 miles west).[3]	658-1,485				Two wells, for oil; unsuccessful.
Los Angeles (10 miles north of west).[4]	520				Two wells, sulphur water and some gas; abandoned.
Norwalk	480	4			
Pasadena	1,200				No water.
Pico	600-735				Numerous oil wells.
Puente[6]	100-1,750				Do.
San Gabriel	+ 500	7			
Madera County:					
Madera[7]	1,200			— 3	
Do	680			+ 1/10	
Madera (6 miles west)	633	7	¾	Flows.	
Mendocino County:					
Potter Valley	400			— 11	
Merced County:					
Atwater	400	7	5		
Dos Palos	442-550				Several wells.

[1] Cal. State Mining Bureau, 12th Rept., 1893-94, pp. 353-354; record, Cal. State Mining Bureau Bull. No. 3, Gas and Petroleum Yielding Formations, Central Valley, p. 30.

[2] Ibid., 11th Rept., 1891-92, p. 489.

[3] Ibid., Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 14-17.

[4] Ibid., 7th Rept., 1887, p. 78.

[5] Ibid., p. 77.

[6] Ibid., Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 18-21.

[7] Ibid., 11th Rept., 1891-92, p. 211.

CALIFORNIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Merced County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Los Banos[1]	434			Flows.	
Merced	600–700	9	167–175		
Merced (13 miles southwest).	1,013	10		+ 1½	Strongest flow at 665 and 680 feet.
San Lewis Ranch	410–426	7	128–160		Two wells.
Modoc County:					
Cedarville	433			No flow.	
Eagleville	508	4½			
Monterey County:					
Salinas	1,435	8		− 6	
Do	1,100	11–9		− 10	
Seaside (near)	617		30	Flows.	Main flow at 610 feet. Water-bearing beds at 270 and 540 feet.
Napa County:					
St. Helena	2,000				
Orange County:					
Fairview	450	7			
Placer County:					
Auburn	730				
Sheridan[2]	734			− 19	
Plumas County:					
Beckwith	400	3	80	Flows.	
Do	500–800	3	100	Flow.	Numerous wells.
Do	1,000–1,200	2–3	Many.	Flow.	
Beckwith (8 miles above).	900	3	Many.		Very warm mineral water.
Summit	400–800	3	5–125	Flow.	Numerous wells.
Do	1,008	3–4		Flow.	
Vinton	700		150	Flows.	
Riverside County:					
Riverside	580	10	Many.	Flows.	
Winchester	400				
Sacramento County:					
Arcade	2,160				
Sacramento[3]	876				Gas well.
Do.[3]	965				Do.
Do.[3]	970			Flows.	Water salty and alkaline.
Sacramento (9 miles northeast).[4]	2,250			Flows.	Some gas.
San Bernardino County:					
Chino (about 2½ miles northwest).	600				Abandoned.
Colton[5]					108 flowing wells.
Danby	630	10	50	+200	
Fenner	800	10	Many.	+200	
Ludlow	1,800		Few.		Not in use.
North Cucamonga	450		Many.		
North Ontario	2,200				Failure.
San Bernardino	605	6	Many.	Flows.	
Do	425	3	76	Flows.	
Do	415	3	7	Flows.	
San Diego County:					
Flowing Well	+ 400				
Point Loma	400	6–5	24	+253	
San Jacinto	450–650	7			Several wells.
San Francisco County:					
San Francisco	865	8–5	87		
San Joaquin County:					
Cutler Salmon Ranch	1,250	7–4			Gas well.
Lathrop Junction	1,420	8		Flows.	Do.
Roberts Island	1,435	7–5		Flows.	Gas well, saline water.
Stockton	420	8		+ 7	Warm water.
Stockton (S. F. and S. J. V. R. R.).	497	7	Many.	− 19	
Stockton[6]	1,002			+ 7	Temp., 77°.
Do	1,400–2,000				Gas wells.
Stockton (Jackson well)[7]	1,700	12–9½	Many.		Gas well.
Stockton[7]	1,400				Do.
Stockton Asylum (Jackson well).[8]	+600–1,750		Many.		Two gas wells.
Stockton (St. Agnes College).[8]	1,720		Many.		Do.
Stockton (court-house)[9].	1,917	12–8	Many.		Gas well.
Stockton (Citizens' Gas Co.).	2,061		Many.		Do.

[1] Record, Cal. State Mining Bureau, 10th Rept., 1890, p. 326.
[2] Ibid., 11th Rept., 1891–92, p. 319.
[3] Cal. State Mining Bureau, 12th Rept., 1893–94, p. 350.
[4] Record, ibid., 10th Rept., 1890, p. 505.
[5] Physical Data and Statistics of California (State Eng. Dept.), 1886, p. 530.
[6] Record, Cal. State Mining Bureau, 8th Rept., 1888, pp. 559–560.
[7] Ibid., Bull. No. 3, Gas and Petroleum Formations, Central Valley, p. 17.
[8] Ibid., p. 18.
[9] Ibid., pp. 15–16.

CALIFORNIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
San Joaquin County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Stockton	980-1,080	.....	Many.	Flow.	Several wells; temp., 75°.
Stockton (9 miles southeast).	1,404	7-5	Many.	.....	Some gas.
San Luis Obispo County:					
San Luis Obispo	928	.....	Many.	Flows.	For oil; unsuccessful. Sulphur water; temp., 103°; gas at 600 feet.
Santa Barbara County:					
Carpinteria (2 miles from).[1]	700	.....	.....	.....	Oil and gas well.
Moody Gulch[1]	1,400	.....	.....	.....	For oil or gas.
Mount Diablo	900	.....	.....	.....	
Santa Barbara (7 miles east).[2]	400-1,600	.....	.....	.....	Several oil wells; some abandoned.
Wasioja (10 miles northwest).	715	.....	.....	.....	Large flow of water at 670 feet.
Santa Clara County:					
Alviso	496	7	.....	+ 0.5	
Do	740	7	.....	+ 1.2	
Do	550	7	.....	Flows.	
Mayfield	604	7	100	Flows. ?	
Milpitas	500-700	7	.....	+ 2	2 wells.
San Jose	442-700	7	Many.	Flow.	Several wells.
Do	400	8	900	Flows.	
Santa Clara	600	.....	Many.	+10	Temp., 60°.
Watsonville	540	.....	.....	− 2	
Santa Cruz County:					
Chittenden	800	.....	.....	.....	For oil.
Sierra County:					
Loyalton	525-750	4	50	Flow.	Several wells.
Do	1,000	.....	20	Flows.	Temp. 130°.
Do	400	3	100	Flows.	
Do	620	4	.....	Flows.	
Do	430-512	3	30	Flow.	Several wells.
Rocky Point	1,132	3	20	Flows.	
Do	1,040	4	10	Flows.	
Sattley	625	2	1	Flows.	
Savilla Colony[3]	600	.....	Many.	Flows.	Gas and sulphur water; gas not used.
Sierra Valley	640-888	3	15-45	Flow.	Several wells.
Do	556-900	4	125-300	Flow.	Do.
Do	746	2	16	Flows.	
Siskiyou County:					
Montague[4]	1,300	10-8	.....	.....	Gas well.
Yreka	700	4¼	135	+32	
Sonoma County:					
El Verano[5]	544	.....	.....	No flow.	
Embarcadero[5]	405	.....	.....	+15	
Ethel	442	10	Many.	To surface.	
Santa Rosa (4 miles south).[6]	815	.....	Few.	.....	Flows at intervals.
Stanislaus County:					
Modesto (1 mile east)	1,070	.....	Many.	No flow.	Small flow of gas.
Newman	427	12	.....	Flows.	
Do	445	8	1,250	.....	
Newman Ranch	411	8	.....	4¼	Brackish water.
Tulare County:					
Alila[7]	1,328	9	.....	+ .25	Small flow of gas.
Waukena	868	10	1,050	Flows.	
Grangeville	980	7	.....	+ .10	
Limekiln Canyon (?)	500	.....	.....	.....	Oil well.
Pixley	438	8	Many.	.....	
Do	480	7	Many.	+ .1	
Do	600	8	.....	+ .8	
Do	713	9	.....	+ .3	
Do	730	8	.....	+ .2	
Pixley (1¼ miles northwest).[8]	955	9	.....	+ .2	
Pixley (2 miles east)	600	8	.....	.1	
Pixley (vicinity)	1,150	9	1,200	Flows.	
Do	937	9	.....	+ .2	
Pixley (3 miles west)	858	8	.....	+ .7	
Pixley	1,060	9	.....	Flows.	
Pixley (3 miles southwest).	815	9	.....	+ .2	

[1] Record, Cal. State Mining Bureau, 8th Rept., 1888, p. 548; 11th Rept., 1891-92, p. 489.
[2] Cal. State Mining Bureau, 12th Rept., 1893-94, p. 357.
[3] Ibid., Bull. No. 3, Gas and Petroleum Yielding Formations, Central Valley, p. 20.
[4] Ibid., 12th Rept., 1893-94, p. 351.
[5] Record, ibid., 11th Rept., 1891-92, p. 457.
[6] Ibid., p. 456.
[7] Cal. State Mining Bureau, 11th Rept., 1891-92, p. 488.
[8] Ibid., p. 487.

CALIFORNIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Tulare County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Pixley (6 miles southwest).[1]	1,150	9	.....	+ 1	
Pixley (6 miles west)	950	8	.....	+ .7	
Pixley (10 miles southwest).[2]	895	10	.....	+ .4	
Pomona	450–550	6 and 9	.....	.....	
Tipton	400	7	.....	+ .04	Several wells about same depth.
Do	480	8–6	.....	+ .04	
Do	503–1,012	8–9	Many.	Flow.	Several wells.
Traver	960	7	Few.	.....	
Tulare	400	6	.....	+ .8	
Do	460	7	500	.....	
Tulare (about 20 miles west).	500	7	.....	+ .15	Several wells about t depth.
Tulare (E. Jacob's ranch).	539	9	.....	+ .1	Some gas.
Do.[3]	498	9	.....	+ .1	Do.
Do.[4]	887	9	.....	+ .35	Gas well.
Do	835	9	.....	+ .3	
Tulare (city wells)	552	9	Many.	−15	Several wells.
Tulare	720	8	300	Flows.	Several wells about the depth.
Tulare (about 20 miles southwest; Lambertson ranch).[2]	1,058	9	Many.	+ .75	Gas at 600 and 700 feet.
Tulare (7 miles west)[5]	730	8	.....	+ .35	
Visalia	775	7	190	Flows	
Waukena	450–816	8–9	Many.	Flows.	Several wells.
Ventura County:					
Adams Canyon[6]	40 -2,780	.....	.....	.....	Many oil wells, yielding 900 barrels per month.
Aliso Canyon	600–700	.....	.....	.....	Several oil wells.
Brownstone	400–800	.....	.....	.....	Several wells.
Buckhorn station (4 miles north).	400	.....	.....	.....	Oil well.
Four Forks[7]	700–1,100	.....	.....	.....	Several oil wells.
Kentuck	700–730	.....	.....	.....	Do.
Little Sespe district	805	.....	.....	.....	Oil well.
Mount Cayetana (southwest slope, near Santa Paula Creek).[8]	430–1,170	.....	.....	.....	Several oil wells.
Nordhoff (1 mile south).	500–800	.....	.....	.....	Do.
Peru (1½ miles south)	400–570	.....	.....	.....	Do.
Sisi Canyon	400–800	.....	.....	.....	Numerous oil wells.
Salt Marsh Canyon[9]	400–1,600	.....	.....	.....	Several oil wells.
Santa Paula region	530–800	.....	.....	.....	Do.
Silverthread oil district (near Santa Paula Creek)[10]	400–1,600	.....	.....	.....	Numerous oil wells.
Tar Creek[7]	700–1,000	.....	.....	.....	Do.
Tar Creek Canyon	400–905	.....	.....	.....	Do.
Torrey Canyon	450–1,000	.....	Many.	Flow.	Oil wells.
Wheeler Canyon[9]	400–900	.....	.....	.....	Several wells.
Wild Bill Gulch[9]	850–975	.....	.....	.....	Oil wells.
Yolo County:					
Grafton	450	6	Many.	.....	

[1] Cal. State Mining Bureau, 11th Rept., 1891–92, pp. 487–488.
[2] Ibid., p. 488.
[3] Ibid., p. 489.
[4] Ibid., pp. 488–489.
[5] Ibid., p. 487.
[6] Ibid., Bull. No. 11, Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara counties, part 1, pp. 35–36.
[7] Ibid., p. 27.
[8] Ibid., pp. 37–38.
[9] Ibid., pp. 36–37.
[10] Ibid., pp. 33, 35, 37.

PUBLICATIONS RELATING TO DEEP BORINGS IN CALIFORNIA.

California State Mining Bureau, Seventh Annual Report of the State Mineralogist for the year ending October 1, 1887, 315 pages, Sacramento, 1888.

California State Mining Bureau, Eighth Annual Report of the State Mineralogist for the year ending October 1, 1888, 948 pages, plates, Sacramento, 1888.

California State Mining Bureau, Tenth Annual Report of the State Mineralogist for the year ending December 1, 1890, 983 pages, plates, Sacramento, 1890.

Physical Data and Statistics of California (State Eng. Dept.), 1886.

CALIFORNIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
San Joaquin County—Cont'd.					
Stockton	980–1,080		Many.	Flow.	Several wells; temp., 75°.
Stockton (9 miles southeast).	1,404	7–5	Many.		Some gas.
San Luis Obispo County:					
San Luis Obispo	928		Many.	Flows.	For oil; unsuccessful. Sulphur water; temp., 103°; gas at 600 feet.
Santa Barbara County:					
Carpinteria (2 miles from).[1]	700				Oil and gas well.
Moody Gulch[1]	1,400				For oil or gas.
Mount Diablo	900				
Santa Barbara (7 miles east).[2]	400–1,600				Several oil wells; some abandoned.
Wasioja (10 miles northwest).	715				Large flow of water at 670 feet.
Santa Clara County:					
Alviso	496	7		+ 0.5	
Do	740	7		+ 1.2	
Do	550	7		Flows.	
Mayfield	604	7	100	Flows. ?	
Milpitas	500–700	7		+ 2	2 wells.
San Jose	442–700	7	Many.	Flow.	Several wells.
Do	400	8	900	Flows.	
Santa Clara	600		Many.	+10	Temp., 60°.
Watsonville	540			− 2	
Santa Cruz County:					
Chittenden	800				For oil.
Sierra County:					
Loyalton	525–750	4	50	Flow.	Several wells.
Do	1,000		20	Flows.	Temp. 130°.
Do	400	3	100	Flows.	
Do	620	4		Flows.	
Do	430–512	3	30	Flow.	Several wells.
Rocky Point	1,132	3	20	Flows.	
Do	1,040	4	10	Flows.	
Sattley	625	2	1	Flows.	
Savilla Colony[3]	600		Many.	Flows.	Gas and sulphur water; gas not used.
Sierra Valley	640–888	3	15–45	Flow.	Several wells.
Do	556–900	4	125–300	Flow.	Do.
Do	746	2	16	Flows.	
Siskiyou County:					
Montague[4]	1,300	10–8			Gas well.
Yreka	700	4¼	135	+32	
Sonoma County:					
El Verano[5]	544			No flow.	
Embarcadero[5]	405			+15	
Ethel	442	10	Many.	To surface.	
Santa Rosa (4 miles south)[6]	815		Few.		Flows at intervals.
Stanislaus County:					
Modesto (1 mile east)	1,070		Many.	No flow.	Small flow of gas.
Newman	427	12		Flows.	
Do	445	8	1,250		
Newman Ranch	411	8		4¼	Brackish water.
Tulare County:					
Alila[7]	1,328	9		+ .25	Small flow of gas.
Waukena	868	10	1,050	Flows.	
Grangeville	980	7		+ .10	
Limekiln Canyon (?)	500				Oil well.
Pixley	438	8	Many.		
Do	480	7	Many.	+ .1	
Do	600	8		+ .8	
Do	713	9		+ .3	
Do	730	8		+ .2	
Pixley (1¼ miles northwest).[8]	955	9		+ .2	
Pixley (2 miles east)	600	8		.1	
Pixley (vicinity)	1,150	9	1,200	Flows.	
Do	937	9		+ .2	
Pixley (3 miles west)	858	8		+ .7	
Pixley	1,060	9		Flows.	
Pixley (3 miles southwest).	815	9		+ .2	

[1] Record, Cal. State Mining Bureau, 8th Rept., 1888, p. 548; 11th Rept., 1891–92, p. 489.
[2] Cal. State Mining Bureau, 12th Rept., 1893–94, p. 357.
[3] Ibid., Bull. No. 3, Gas and Petroleum Yielding Formations, Central Valley, p. 20.
[4] Ibid., 12th Rept., 1893–94, p. 351.
[5] Record, ibid., 11th Rept., 1891–92, p. 457.
[6] Ibid., p. 456.
[7] Cal. State Mining Bureau, 11th Rept., 1891–92, p. 488.
[8] Ibid., p. 487.

COLORADO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Rem
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bent County:					
Caddoa	582				Water at va
Fort Lyon	815				Abandon amount o feet.
Fort Lyon, northeast of	780			−200 or −580?	
Las Animas	+ 500		82		
Las Animas (7 miles northeast).	815		(?)	Flows.	Small amou 430 feet.
T. 21, R. 52, sec. 36	720			−300	Good water stone fron but well a failure.
Do	418			−150 or −268	
Boulder County:					
Boulder	400	2	5	Flows.	
Do	+1,000			+ 20	Water too a
Boulder (4 miles east)	600				Unsuccessf
Hygiene[1]	905				Flowed at 6
Langford (4 miles northeast).	400	2	3	Flows.	
Longmont	431	4	+ 2		
Do	506			No flow.	
Do	600	6	40	+ 30	
Do	640	3½	Few.		
Cheyenne County:					
Cheyenne Wells[2]	1,770				For water;
Do	1,700				For gas; fai
Kit Carson	1,460				No fresh wa at 450 feet
Clear Creek County:					
Georgetown	658	2	120	+ 100	
Conejos County:					
Alamosa	505	3	3	Flows.	
Do	604	3	225	Flows.	
Do.[3]	856	6–8	1,000	Flows.	Temp., 65°.
Do	465	3½	Many.	Flows.	
Do	474	2	Many.	Flows.	
Do	1,000	7½-6	Many.	Flows.	Temp., 75°.
Do	900	8	Many.	Flows.	2 wells; ten
Costilla County:					
Mosca	610	4½		+ 3	
Do	420	4		Flow.	
Custer County:					
Colfax	627		7	Flows.	
Westcliffe	500		None.		Abandoned
Delta County:					
Delta	575	2½	Few.	Flows.	
Do	580	3		Flows.	
Denver County:					
Denver (east of)	795				Unsatisfact
Denver (St. Luke's Hospital).					Large flow
Denver	400–1,100				Several hun
Do	1,350–1,500				Water from mie and considera ized.
Douglas County:					
Acequia	442		15	Flows.	
Do	596		4	Flows.	
Castle Rock	1,700				Failure.
Larkspur	560				
Do	502				Dry; aband
Sedalia	650	2½			
Do	710			No flow.	
Do	1,440				Water from only.
Sedalia (5 miles south)[4]					
El Paso County:					
Calhan[5]	566	6			Saline wate
Colorado City	2,020				Gas pressur square in with surf
Do	1,300				Gas at 216 f water. (low 35 fe

[1] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 208.
[2] Record, U. S. Geol. Surv., 16th Ann. Rep., 1894–95, part 2, p. 563.
[3] Record, 51st Congress, 1st sessi Doc. No. 222, 1890, p. 223.
[4] Ibid., p. 207.
[5] Ibid., p. 216.

COLORADO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
El Paso County—Continued.					
Colorado Springs	1,120				
Franceville Junction	Many.				
Fremont County:					
Canon City	1,600		700	+100	Temp., 90°.
Canon City (near)	1,278	4¼	½	-- 15	Water at 350 feet.
Canon City (5 miles south).	1,000	4	Many.	Flows.	For oil, two wells.
	460	8¼-5			
Chandler (one-half mile southwest).	487	3¼	Many.	Flows.	Water at various (soft water, with iron and sulphur
Chandler (three-fourths mile southwest).	1,075	4¼	Many.	Flows.	Water soft, with litt
Florence[1]	780		1	Flows.	Numerous oil well: cinity.
Do	+1,000		700	Flows.	Water at 1,000 feet.
Do	+ 800		1,000	Flows.	Temp., 86°.
Do	3,021¼				No water.
Westcliffe	+ 500				
Huerfano County:					
Rouse Junction	2,058		Few.	—200	Salt water at 890 fee amounts of wate and 1,600 feet.
Walsenburg	1,250				For gas, entirely in salt water at —40
Jefferson County:					
Arvada	460			Flows.	
Kiowa County:					
Sheridan Lake	1,280	6		50	Water at 1,200 feet: doned.
Kit Carson County:					
Burlington	600		Small.	Flows.	
Lake County					
Leadville	400		30		
La Plata County:					
Durango	400			Flows.	
Larimer County:					
Loveland[2]	2,465		1	Flowed.	Water at 1,365 feet.
Stout[2]	1,225		1	+ 30	Poor water, 922 to 1,0
Las Animas County:					
Barela	1,840				
Do	+1,040		30	—300	
Hoehne	936				Well abandoned.
Thatcher	920	5¼		—620	
Salt Creek	2,050				Unsuccessful in fin sufficient supply (water.
Troy	400 or 500				
Trinidad	2,595	5¼	Many.	—195	
Do	2,713				Shale water from 250 feet.
Logan County:					
Fleming	423			—160	Very small supp water.
Mesa County:					
Grand Junction	1,000	6¼-5¼	Few.	No flow.	Some gas at 444, 7 864 feet.
Montezuma County:					
Cortez (9 miles southwest).[3]	795		Several.	No flow.	
Montrose County:					
Montrose	825		30	Flows.	Temp., 72°.
Otero County:					
Fowler	1,372				Flow of soft wate upper sandstone Dakota.
Holbrook	661		100	+ 80	Penetrated the sandstone 110 fee
Iron Springs	1,162			—556	Flows at 240 and 3 unsatisfactory w 1,006 feet.
Lajunta[4]	405		8	Flows.	
	412	4¼	8	Flows.	Temp., 68°.
	420	8-6	45	Flows.	2 wells; temp., 70°.
	439	6			Temp., 68°.
	640	5¼	35	Flows.	Do.
	670	8¼	15	Flows.	
	700	6			Do.
	740		15	Flows.	
	740	7¼	12¼	+ 20	Temp., 75°.
	766	7¼	25		Temp., 68°.
	1,152	5¼	Many.	Flows.	

[1] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, pp. 214.
[2] Ibid., pp. 210-211.
[3] Record, Colorado State Engineer, Eigh nual Report, 1895-96, pp. 69-70.
[4] Ibid., Ninth Biennial Report, 1897-98, pp

COLORADO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Otero County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Lajunta (2¼ miles south)	1,703				For gas or oil; unsuccessful.
Las Animas (northeast)	715			-60	
Manzanola	1,113	5⅝	42	Flows.	Temp., 80°.
Do	2,110				To test for oil or gas; unsatisfactory result; abandoned.
Ordway	1,575	4¼	Many.	-250	Temp., 63°.
Do	1,508			-90	
Ordway (18 miles due east).	715		20	-60	
T. 21, R. 50, sec. 36	780				
Rockyford	767	5¼	130	Flows.	Temp., 78°.
Do	790	10–4¼	68	+75	Temp., 74°.
Do	793	7⅛	68	Flows.	Temp., 78°.
Do	820	7⅛	38	Flows.	Temp., 75°.
Do.[1]	845	4	115	Flows.	Temp., 72°.
Do	1,033	6	17	Flows.	Temp., 75°.
Sugar City	1,308				Reached Dakota sandstone at 1,230 feet.
Timpas	795	6¼	35	Flows.	
Wyckoff Park (near Rockyford).	855	4	115		
Prowers County:					
Amity	699	8–6		-100	Good water at 300 feet.
Granada	504		80	No flow.	
Lamar[2]	527	5⅝	5	Flows.	Can pump 80 gallons.
Lamar (northwest)	420			No flow.	
Pueblo County:					
Boone (2 miles north)	2,175				For oil or gas; unsuccessful.
Pueblo[3]	772	4¼	2¼	Flows.	
Do	782		3–5	Flows.	
Do	789	5⅝	300	Flows.	
Do	1,150		13	Flows.	Pressure, 60 pounds.
Do	1,219	4¼	20	+125	Temp., 76°; pressure, 50 pounds.
Do	1,260		20–25	Flows.	
Do	1,400	3	¼	+140	Temp., 77°.
Do	1,402		+87	+140	
Pueblo (7 miles northeast).	1,900			550	For oil or gas; unsuccessful.
Pueblo (10 miles northeast).	2,655			-100	Do.
North Pueblo Heights	1,820				Small flows at 1,200 and 1,820 feet.
Pueblo (south)	1,412	6	100	Flows.	Pressure, 60 pounds; mineral water.
Salt Creek	2,030			No flow.	Small amount of water at various depths; abandoned.
Rio Blanco County:					
Whiteriver	402				Salt water at 200 feet.
Do	506¼				Much gas at 500 feet.
Rio Grande County:					
Del Norte	607			Flows.	
Saguache County:					
Cotton Creek	405	3	75	Flows.	Temp., 58°.
Crestone	426	3	10	Flows.	
Do	446	3	75	Flows.	
Lockett	418	3		+11	
Moffat	404	3	Few.	Flows.	
Do	650			Flows.	
Do	710	2		+1¼	
Saguache	400	1¼			
Washington County:					
Akron	1,155	10–6			Failure; abandoned.
Otis[4]	2,400		None.		Abandoned.
Weld County:					
Eaton	970			No flow.	Much water at 230 to 260 feet.
Evans	1,125		Few.	Flows.	Water from 1,125 feet.
Fort Lupton	904			.1	
Greeley[5]	446	2¼	¼	No flow.	
Do	970	4		.20	

[1] Record, Colorado State engineer, Ninth Biennial Report, 1897–98, pp. 28–29.
[2] Ibid., p. 29; analysis, 51st Cong., 1st session, Senate Ex. Doc. No. 222, 1890, p. 228.
[3] Record, 51st Cong., 1st session, Senate Ex. Doc. No. 222, 1890, pp. 213–214; analysis, ibid., p. 229.
[4] Ibid., p. 217.
[5] Ibid., pp. 209–210.

COLORADO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
El Paso County—Continued.					
Colorado Springs	1,120				
Franceville Junction	Many.				
Fremont County:					
Canon City	1,600		700	+100	Temp., 90°.
Canon City (near)	1,278	4¼	⅓	-- 15	Water at 350 feet.
Canon City (5 miles south).	1,000	4	Many.	Flows.	For oil, two wells.
	460	8¼-5			
Chandler (one-half mile southwest).	487	3¼	Many.	Flows.	Water at various depths; soft water, with little iron and sulphur.
Chandler (three-fourths mile southwest).	1,075	4¼	Many.	Flows.	Water soft, with little iron.
Florence [1]	780		1	Flows.	Numerous oil wells in vicinity.
Do	+1,000		700	Flows.	Water at 1,000 feet.
Do	+ 800		1,000	Flows.	Temp., 86°.
Do	3,021¼				No water.
Westcliffe	+ 500				
Huerfano County:					
Rouse Junction	2,058		Few.	—200	Salt water at 890 feet, small amounts of water at 700 and 1,600 feet.
Walsenburg	1,250				For gas, entirely in shale; salt water at —40 feet
Jefferson County:					
Arvada	460			Flows.	
Kiowa County:					
Sheridan Lake	1,280	6		50	Water at 1,200 feet; abandoned.
Kit Carson County:					
Burlington	600		Small.	Flows.	
Lake County					
Leadville	400		30		
La Plata County:					
Durango	400			Flows.	
Larimer County:					
Loveland [2]	2,465		1	Flowed.	Water at 1,365 feet.
Stout [2]	1,225		1	+ 30	Poor water, 922 to 1,000 feet.
Las Animas County:					
Barela	1,840				
Do	+1,040		30	—300	
Hoehne	936				Well abandoned.
Thatcher	920	5¼		—620	
Salt Creek	2,050				Unsuccessful in finding a sufficient supply of good water.
Troy	400 or 500				
Trinidad	2,595	5¼	Many.	195	
Do	2,713				Shale water from 150 to 250 feet.
Logan County:					
Fleming	423			—160	Very small supply of water.
Mesa County:					
Grand Junction	1,000	6¼-5¼	Few.	No flow.	Some gas at 444, 700, and 864 feet.
Montezuma County:					
Cortez (9 miles southwest). [3]	795		Several.	No flow.	
Montrose County:					
Montrose	825		30	Flows.	Temp., 72°.
Otero County:					
Fowler	1,372				Flow of soft water from upper sandstone of the Dakota.
Holbrook	661		100	+ 80	Penetrated the Dakota sandstone 110 feet.
Iron Springs	1,162			556	Flows at 240 and 375 feet; unsatisfactory water at 1,0[illegible]6 feet.
Lajunta [4]	405		8	Flows.	
	412	4¼	8	Flows.	Temp., 68°.
	420	8-6	45	Flows.	2 wells; temp., 70°.
	439	6			Temp., 68°.
	640	5¼	35	Flows.	Do.
	670	8¼	15	Flows.	
	700	6			Do.
	740		15	Flows.	
	740	7¼	12¼	+ 20	Temp., 75°.
	766	7¼	25		Temp., 68°.
	1,152	5¼	Many.	Flows.	

[1] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, pp. 214.
[2] Ibid., pp. 210-211.
[3] Record, Colorado State Engineer, Eighth Annual Report, 1895-96, pp. 69-70.
[4] Ibid., Ninth Biennial Report, 1897-98, pp. 28-29.

CONNECTICUT—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Rema
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
New Haven County:					
Meriden	530	12	70	No flow.	Water very ha
New Haven	3,800				Unsuccessul.
Do	4,000	8			
Southbury[1]					
New London County:					
Mystic	530		1		
Tolland County:					
Mansfield	800	6	14	No flow.	
Do	850	6	40	−36	
Rockville	3,440		Not any.		Abandoned.
Windham County:					
Pomfret	600				
Pomfret Center	610	6	12	−25	
Putnam Heights	800		Few.	No flow.	
Do	400	6	4	No flow.	
Do	700		7	No flow.	
Do	420	6	2	No flow.	
Do	6,004	6	2	4	

[1] Am. Jour. Sci., vol. 62, p. 275, 1890; also Hobbs, 21st Ann.

DELAWARE.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Kent County:					
Bowers Beach[1]	500	3¼	200	No flow.	Not much water be 240 feet.
Newcastle County:					
Fort Dupont[2]	734	8	Many.	Flows.	
Middletown[3]	535	10–8	330	−50	Water also at 475 feet.
Do.[4]	698				Water from 535 and 6 686 feet.
Do.[5]	821		Many.	−35	
Wilmington	400	8	15–18		
Do	1,077		10	25	
Do	416				
Reedy Island[6]	570		20	Flows.	
Sussex County:					
Delmar[7]					
Lewes[8]	400	6	15	At surface.	
Do.[8]	1,080		15	Flows.	

[1] N. J. Geol. Surv. Rept., 1899, p. 110.
[2] Record, N. J. Geol. Surv. Rept., 1900, pp. 132–134; 1901, pp. 105–107.
[3] Record, U. S. Geol. Surv. Bull. No. 138, p. 123.
[4] Record, N. J. Geol. Surv. Rept., 1898, p. 115.
[5] Ibid., 1901, pp. 107–109.
[6] Ibid., 1897, pp. 248–249.
[7] Ibid., 1899, pp. 111–112.
[8] Ibid., 1898, pp. 83–87.

LIST OF PUBLICATIONS RELATING TO DEEP BORINGS IN DELAWARE.

New Jersey Gelogical Survey Reports, by the State Geologist, for 1897, 1898, 1899 900, and 1901.

Artesian well prospects in the Atlantic Coastal Plain region, by N. H. Darton nited States Geological Survey Bulletin No. 138.

DISTRICT OF COLUMBIA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
ington, Heurich's old wery.	900		7		Abandoned.
ington, Riggs House	558		None.		Unsuccessful.

FLORIDA.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
ity:					
.....	529	8	300	− 81	
ty:					
.....	425	.....	100	+ 18	
.....	484	6	2,500	+ 46	Temp., 78°.
.....	435	1¼	Many.	+Many.	
.....	530	4	Many.	+ 10	
.....	450	4	Many.	+ 30	
.....	440–465	4	Many.	+0 to 21	3 Wells.
.....	460	4	Many.	+ 16	
.....	510	3	Many.	Flows.	Temp., 78°; bored for oil, none found.
.....	400	6	.....	+ 48	Temp., 78°.
.....	480	4	Few.	Flows.	Sulphur water.
.....	462–450	6	Many.	Flow.	2 wells.
e Springs	600	6	600	+ 30	Temp., 80°.
.....	673	4	150	+ 15	
.....	815	4	300	+ 33	
nty:					
.....	+400	.....	Many.	.....	
.....	520	10	.....	− 100	
.....	1,200	4	.....	.....	
nd	1,100	6–4	Several.	+ 6	Sulphur water.
th[1]	1,212	4	313	+ 40	
h	1,200	4	Several.	Flows.	
ty:					
da	467	.....	.....	.....	Water too salty for use.
.....	400	.....	.....	Flows.	
.....	425	.....	25	Flows.	Salt water only.
.....	408	8	650	+ 40	
.....	650	3	80	+ 6	
.....	800	.....	.....	.....	
:					
lle[2]	793	6	.....	+ 17	
.....	711	.....	.....	Flows.	Sulphur water.
.....	630	6	432	.....	Temp., 74° to 77°.
.....	660	6	950	+ 64	Do.
.....	1,020	10	.....	.....	Temp., 81°.
.....	937	12	432	.....	Temp., 77°.
.....	490	3	180	+ 62	Temp., 75°.
.....	637	6	600	+ 62	Temp., 76°.
.....	650	6	900	+ 62	Do.
.....	1,020	.....	2,333	+ 62	Temp., 78°.
.....	.....	8–4	.....	.....	
.....	616–5,000	4–8	60–400	+2–50	7 wells.
.....	625	4	Many.	+ 40	
.....	600	4	.....	+ 20	
.....	700	8	Many.	Flows.	
as	678	6	Many.	+ 30	
.....	750	6	.....	+ 60	Temp., 77°.
ksonville	800	.....	.....	+ 55	
.....	750	6	.....	+ 69	Do.
nty:					
.....	1,400	.....	.....	.....	Navy-yard well; no good water.
.....	1,252–1,702	4¼	.....	.....	4 wells.
nty:					
ola	475	3¼	.....	.....	Temp., 68°.
.....	450	3	40	+ 4	
ity:					
.....	610	6–4¼	.....	− 190	
nty:					
.....	+550	.....	.....	.....	In progress.
am	406 and 407	3	200	Flow.	2 wells.
s	406–575	2–4	100–200	+4–40	7 wells.
City	400	.....	.....	.....	
e	715	.....	.....	98	
ity:					
.....	530	6	100	− 117	
ity:					
.....	400	4	Many.	+ 20	
.....	450	4	20	+ 10	
.....	426	3	.....	+ 4	
.....	400	6	.....	+ 3	
y:					
.....	1,200	.....	.....	− 15	
.....	1,210	8	.....	− 74	
.....	1,400	.....	.....	− 30	

d, Am. Jour. Sci., 3d ser., vol. 41, pp. 105–106.

[2] Representative wells.

FLORIDA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Monroe County:					
Key West	2,350				
Nassau County:					
Fernandina[1]	640	8	800	+ 50	Water from 618 fee
Do	750	6		+ 64	Temp., 77°.
Fernandina (city park)	700	8	810	+ 40	Temp., 74°.
Fernandina	762				
Heart's Road? (railroad junction).	750	6	Many.	+ 64	Temp., 77°.
Osceola County:					
Kissimmee	406	4			
Do	606				
Narcoossee	416	3		+ 27	
Polk County:					
Bartow (8 miles southwest).	600				Small.
Do	400				
Bartow	725				Water.
Pasco County:					
Pasadena	450			+ 86	
Putnam County:					
Huntington	420	4	Several.	+ 12	
Riverside			Many.	Flow.	2 wells.
St. John County:					
St. Augustine[2]	1,400		5,500		Temp., 86°. Stro also at 400–450 550 feet.
Do	1,500		Many.	Flows.	
St. Augustine	1,278				Flows at 468, 1, 1,200 feet; latter with lime." F at 1,225 feet.
n wanee County:					
Liveoak	1,050	6	Many.	+ 54	
Volusia County:					
De Land	485	6	50	+ 22	
Washington County:					
Caryville	769	4½	Many.	+ 10	

GEORGIA.

Appling County:					
Baxley[3]	507	6		+ 129	Water at 320 and
Do	461	8–6	150	+ 90	
Baldwin County:					
Milledgeville	600 or 700		Many.	No flow.	
Bibb County:					
Macon[4]	955	12	Not any.		Abandoned.
Brooks County:					
Quitman[5]	500?	6		30	Water at 109 feet.
Bryan County:					
Ways Station[6]	460	3	200	+ 20	Water at 340 and
Do	484	6–2	Many.		
Bulloch County:					
Statesboro	415	7–4½	40	+ 100	
Do	(?) 600	4			
Burke County:					
Dry Creek[7]	763	2		+ 30	Water also at 280 feet.
Midville	750	5	75	+ 47	Water-bearing be 300 and 450 fee hard, containi iron and sulphu 68°.
Sebastopol	676	6		+ 2	Water at 200, 345, feet.
Waynesboro[8]	992	6		+ 14	Water at 250, 300, feet.
Do	1,260	8		+ 52	
Do	760			No flow.	
Do	425			No flow.	
Do	618	4		+ 18	
Do	876	6			Abandoned.

[1] Ga. Geol. Surv. Bull. No. 7, pp. 75–76.
[2] Am. Jour. Sci., 3d ser., vol. 34, p. 70.
[3] Ga. Geol. Surv. Bull. No. 7, p. 149.
[4] Ibid., p. 193.
[5] Record, ibid., pp. 156–157.
[6] Ibid., pp. 111–112.
[7] Ga. Geol. Surv. Bull. No. 7, p. 128.
[8] Record, ibid., pp. 125–126.

GEORGIA—Continued.

n.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
.....	625	6	.....	− 20	Water at 500, 600, and 700 feet; hard and slightly chalybeate.
.....	672	5-2	23	+ 30	
north).....	400	.....	.....	No flow.	Abandoned.
Island[3]	600	4	.....	+ 12	
.....	485	4	.....	+ 12	
.....	680	6	555	+ 51	Water sulphurous.
.....	475	2	60	Flows.	
.....	500	2	33½	+ 20	
.....	525	4	Many.	+ 50	Water at 300 and 500 feet.
iles north-	414	2	Many.	+ 50	
.....	450	4	300	− 60	Water at 130 and 450 feet.
.....	+ 650	.....	.....	− 18	
.....	1,500	12	Many.	No flow.	
.....	500	10	.....	.....	2 wells reported.
.....	402–470	6	Many.	.....	5 wells of old waterworks.
.....	475–700	12	13 wells 4,861	.....	City waterworks comprising 13 wells.
niles south)	1,147	4	.....	+ 31	
miles west Ogeechee	+ 659	.....	.....	Flows.	Temp., 72°.
.....	650	4-3	150	− 20	
.....	800	.....	400	− 12	
.....	750?	2	7	+ 2	
.....	571–506	.....	450	−240	2 wells.
on.....	+ 400	.....	.....	.....	
.....	900	6-2	.....	− 50	
.....	1,325	.....	.....	.....	Water at 280 and 370 feet.
.....	965	6-2	.....	− 59	
.....	525	6	.....	− 70	Water at about 300 feet.
.....	680	4	200	− 120	
.....	+ 600	.....	Not any.	.....	Abandoned.
.....	720	.....	.....	− 200	
.....	550	8	.....	− 20	
.....	700	6	.....	− 30	
.....	400	8	.....	− 18	
.....	400	8	8	Flows.	Temp., 50°.
y:					
.....	665	2	20	Flows.	
.....	700–780	6-4	20–115	+ 24	Numerous wells; temp., 73½°.
.....	732	10	225	+ 30	
iles west)...	550	.....	.....	.....	Pure water.
n[17].....	547	2	.....	+ 10	
s..... ...	539	6	12	20	
.....	547	2	.....	− 7	Water also at 200 feet.
y:					
.....	750	4	.....	− 45	Water at 300 and 750 feet.
.....	538	6	Many.	Flows.	
.....	400	6	21	− 80	
.....	400	2	10	90	
.....	1,200 and 1,850	6?	.....	3	2 wells.
.....	638	14	56	− 12	

alysis, Ga. Geol. Surv. Bull. No.

pp. 186–187.
, pp. 78–79.
pp. 76–77.
. Bull. No. 7, p. 79.
.

pp. 114–120.
, pp. 160–161.

[11] Ibid., p. 162.
[12] Ga. Geol. Surv. Bull. No. 7, p. 145.
[13] Analysis, ibid., pp. 144–145.
[14] Record, ibid., pp. 159–160.
[15] Analysis and record, ibid., pp. 179–181.
[16] Record, ibid., pp. 178–179.
[17] Ibid., p. 182.
[18] Ibid., pp. 183–184.
[19] Ibid., pp. 121–122.
[20] Ibid., p. 43.

GEORGIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Glynn County:					
Bladen[1]	480	3	100	+ 30	Water at 160, 260, feet.
Brunswick[2]	450–490	3	200	+ 28	Numerous wells.
Do	415	3	.....	+ 19	Temp., 62°.
Do	540	8	600	+ 12	
Do	430	4	.....	+ 25	
Do	460	6	350	+ 12	
Do	465	4	600	Flows.	Temp., 70°.
Do	405–822	2¼–4	15–400	+10 to + 57	12 wells.
Evelyn	420	3	.....	+ 14	Sulphur water.
Everett City	460	2	.....	+ 38	
Jekyl Island[3]	480	6	250	+ 45	
St. Simons Island	480	6–3	100–150	.....	3 wells.
Do.[4]	438	6	250	+ 40	Water 350 and 435
Houston County:					
Fort Valley[5]	1,075	6–4	.....	−100	
Do	500	.....	Not any.	.....	Abandoned.
Do	1,200	.....	Not any.	.....	
Irwin County:					
Fitzgerald[6]	680	6–3	.....	− 27	
Do	800	10	.....	−150	
Do	1,000	6	.....	−128	
Do	853	12–8	139	−320	
Jefferson County:					
Bartow	525	3–2	3	+ 10	
Louisville[7]	450	4	.....	.....	Several wells; t low ground flo
Wadley[8]	445	6	Many.	+ 20	13 wells report also at 330 feet.
Johnson County:					
Wrightsville[9]	672	8	.....	− 60	Water at 430 and
Do	763	3	.....	− 63	
Laurens County:					
Dublin	850	8	.....	.....	First flow at 350 f
Lee County:					
Albany	450	6–2	25	− 68	
Leesburg	500–600	8	.....	No flow.	Temp., 68°; miner
Do	540	6–4	5	− 12	
Smithville[10]	900	2¼, 4	Many.	+ 20	2 wells.
Liberty County:					
Riceboro[11]	460	3	150	+ 20	
Do.[12]	430	4	100	+ 24	Soft water.
Lowndes County:					
Valdosta[13]	522	8	.....	−113	Temp., 70°; wate 450, and 515 fee
Do	500	10	25	−120	
McDuffie County:					
Thomson	506¼	8–6	8	+ 1	
McIntosh County:					
Barrington[14]	450	3	200	+ 20	Flows at 350 and
Creytons Island[14]	414	3	.....	+ 50	
Darien	492	4	.....	.....	
Do.[15]	530	8	200	+ 15	
Doboy	450	6	250	.....	
Evelyn	500	2	.....	+ 45	Sulphurous wate
Valona	455	3	120	+ 60	Temp., 70°.
Macon County:					
Montezuma[16]	500	.....	300	+ 62	2 wells.
Do	425	.....	5	Flows.	Temp., 62°.
Do	425	.....	2	Flows.	Do.
Do	450	2¼	30	+ 26	Flows at 60, 150, feet.
Do	450	4		+ 26	
Oglethorpe	490	2	66	.....	Temp., 62°.
Marion County:					
Buenavista[17]	583	10	.....	− 240	Water at 331 and
Mitchell County:					
Camilla	600	.....	.....	No flow.	Nonflowing.
Montgomery County:					
Lyons[18]	400	3	10	− 84	Main water horiz feet.
McArthur[19]	900	3	.....	− 60	Water at 419 and

[1] Record, Ga. Geol. Surv. Bull. No. 7, pp. 92–93.
[2] Ibid., p. 86.
[3] Analysis, ibid., p. 94.
[4] Ga. Geol. Surv. Bull. No. 7, pp. 74–75.
[5] Record, ibid., p. 192.
[6] Ga. Geol. Surv. Bull. No. 7, p. 152.
[7] Record, ibid., p. 132.
[8] Ibid., p. 131.
[9] Ibid., pp. 137–138.
[10] Ibid., pp. 176–177.
[11] Ga. Geol. Surv. Bull. No. 6, pp. 110–11
[12] Ibid., p. 110.
[13] Analysis, ibid., pp. 154–156.
[14] Ga. Geol. Surv. Bull. No. 7, p. 109.
[15] Record, ibid., pp. 105–108.
[16] Ibid., pp. 189–190.
[17] Ibid., p. 198.
[18] Ibid., p. 146.
[19] Ibid., p. 147.

GEORGIA—Continued.

;ion.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
ıty:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
3 miles south	425	3	2	− 4	Water at 400 feet.
;:					
lle[1]	490	6	.....	Flow.	Temp., 71°.
.....	497	8–4	15	Flows.	
nty:					
.....	1,000	6–4	.....	− 30	Water also at 340–400, and 550 feet.
.....	410	4	60	− 70	
ınty:					
.....	814	8	18	−196	Water at 500, 600, and 700 feet; hard and slightly chalybeate.
.....	879	6	.....	.....	5 water-bearing strata penetrated.
y:					
.....	430–450	4–6	.....	+ 19	Several wells.
r:					
ılantation[5]	740	3	.....	Flows.	Water from 475 feet.
3 miles west tahoochee	490	6	⅛	+ 20	
.....	490	2	⅛	+ 20	
.....	445	.....	1½	+ 30	
.....	455	.....	¼	+ 20	
.....	420	6	25	−120	
:					
.....	1,725	8–4	.....	− 30	Water at 1,000 feet.
.....	400	.....	.....	− 10	Supply is derived from the 350-foot level.
.....	500	.....	.....	− 10	
.....	900	.....	.....	Flows.	
.....	550	4	33	+ 1	
:					
.....	800	8	.....	−142	
.....	447	3	10	− 60	
.....	450	4–2½	.....	− 35	
.....	498	6	.....	−148	
:					
.....	700	8–4	60	− 80	
:					
ty[8]	400	2	60	+ 14	6 wells; water also at 300 feet.
:					
.....	650	5–2	.....	− 45	
.....	540	3–200	50	−28 to −40	2 wells.
y:					
le[10]	1,900	5½	Many.	−210	
.....	480	8	Many.	−210	
.....	440	8	30?	−175	
.....	700	12	750	− 60	2 wells pure water.
.....	500	6	150	.....	
.....	600	4	.....	− 55	
ounty:					
.....	990	16–4	Many.	−190	Water at 426 and 830 feet.
n	431	4½	.....	−134	
:					
.....	500	2	.....	− 33	Water also at 287 feet.
:					
.....	540	4	.....	− 25	Water at 90, 139, and 296 feet.
ills	673	2½	60	+ 22	Temp., 74°.
.....	+400	.....	.....	No flow.	3 wells reported.
.....	785	6–3½	.....	80	
nty:					
.....	600	3	.....	(?) + 50	
:					
.....	497	8–2	1	− 5	Sulphur water.
.....	430	4½	400	.....	Temp., +70°.
nd	475	4	150	.....	
l	500	2	.....	+ 45	Sulphurous water.

Geol. Surv. Bull. No. 7, p. 140.
ırv. Bull. No. 7, pp. 128–129.
3–124.
l., p. 197.
analysis, ibid., pp. 174–176.
ırv. Bull. No. 7, p. 194.
l., p. 150: Analysis and record, U. S.
ll. No. 138, p. 224.
[9] Ibid., pp. 187–188.
[10] Ibid., pp. 158–159.
[11] Record and analysis, ibid., pp. 96–102.
[12] Record, ibid., pp. 132–136.
[13] Ibid., pp. 103–104.
[14] Ga. Geol. Surv. Bull. No. 7, p. 151.
[15] Ibid., p. 164.

PUBLICATIONS RELATING TO DEEP BORINGS IN GEOR(

Preliminary report on the artesian well system of Georgia, by S. W. 1
Geological Survey of Georgia Bulletin No. 7, 214 pages, plates, Atlanta, 189
Artesian prospects in the Atlantic Coastal Plain region, by N. H. Darton
States Geological Survey Bulletin No. 138, 232 pages, plates, Washington, 1

IDAHO.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarl
Ada County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Boise	450		270	+ 10	Temp., 80°. several wells. average 555 minute, anc height of Temp., 170°.
Boise County:					
Idaho City	+400				Prospect well;
Cassia County:					
Oakley	±400				
Elmore County:					
Cleft	450	8			
Medbury	832	8	70	Flows.	
Fremont County:					
Dubois	615		50	No flow.	Water-bearing at 375 feet.
Lincoln County:					
Bliss	483	8			
Minidoka	425				
Owinza	400				

ILLINOIS.

Adams County:					
Camppoint	1,006				
Mendon [1]	1,010				
Mendon (1 mile west) [1]	400				
Payson	1,542	5¼–4¼	13	–150	Water at 167 an brine at 800 feet.
Quincy	550–1,000				5 wells.
Alexander County:					
Cairo	700–750		556	+ 10	4 wells.
Do	1,025				No water below
Do	1,040				
Boone County:					
Belvidere [2]	1,950	8–4	400	– 6	
Do	1,932	8–6	200	– 6	
Do	1,231	10–6¼	180	– 20	Water-bearing 834, 1,070 and
Bureau County:					
Buda [3]	1,610	6	100		Strong water feet, which out; well limestone, 1,470, then was struck; 4- coal at 225 fe
Ladd [4]	460		135	Flows.	Shaft for coal. gallons at 2 gallons at 173 decreased to 1
Ohio [3]	412				
Princeton [5]	2,500			– 72	
Do	2,092	9¼–4¼	320		Water hard, s line from 1,5 feet and 1,8 feet.
Do. [6]	400				

[1] U. S. Geol. Surv. Monograph No. 38, 1899, p. 715.
[2] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 810; Monograph No. 38, 1899, p. 573.
[3] Ibid., Monograph No. 38, 1899, pp. 628–629.
[4] Columbia College, School of Mines Quarterly, vol. 16, pp. 238–243.
[5] U. S. Geol. Surv., 17th Ann. Rept., 18 2, p. 816; analysis, ibid., pp. 808, 828; M No. 38, 1899, p. 627.
[6] Record, Economic Geology, Ill., vol.

ILLINOIS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Carroll County:					
Mount Carroll[1]	2,502	5			Much water at 1,200 feet; less from 1,300 to 2,500 ft.
Mount Carroll (4 miles south).[1]					
Savanna[1]	1,432		500	+83	
Cass County:					
Beardstown[2]	1,070		17		Water, oil, and gas.
Do.[3]	1,050–1,100		175		Several artesian wells; flow of water at about 350 feet; another flow with small amounts of gas and oil at 500 to 600 feet; a third floor near the bottom.
Virginia	750				Water at 730 and 750 feet; unfit for drinking.
Champaign County:					
Champaign	400				
Do[4]	+663				
Christian County:					
Pana[5]	2,507		Few.		Brackish water.
Clark County:					
Marshall	500				2 unsuccessful oil borings.
Coles County:					
Charleston	2,600				Salt water at 160 and 815 feet.
Do	748½				
Mattoon	1,647	8	Many.		Salt water at 308 feet, and very salty at 1,500 feet.
Cook County:					
Arlington Heights[6]	800				
Austin[7]	1,205		Many.		
Avondale	1,968				
Blue Island	1,649				
Cragin	1,308–1,534				
Cicero	1,571				
Chicago[8]	694	5		−13	Hard water, original head +77 feet.
Do.[8]	711	4¼	400	−13	Original head +77 feet.
Do	1,400				Unsuccessful.
Do.[8]	1,200			At top.	Hard water.
Chicago (Union Stock Yards).[9]	1,105				
Chicago (Lehman well).	2,604				Brackish water.
Chicago (Swift & Co.)	2,700				
Chicago (Stockton)	2,180 2,186		840	- 30	2 other wells.
Chicago	700–2,780				Many wells.
Chicago and Western avenues.[10]	711				Test for oil; small amount of oil, strong flow water.
Do.[11]	694				Flow of water at 694 feet.
Cragin	1,300–1,534				
Evanston[11]	1,602			+ 5	Water at 562 to 832 feet.
Harvey	675–2,075				4 wells.
Do.[12]	1,300 2,075		250	−10	2 wells.
Hawthorne	989				
Do	2,005¼				
Irving Park	2,187				
Kensington	1,656				
Do	1,283				
Lagrange	1,757–2,014			No flow.	
Lemont	1,366			+60	
Maywood	1,595				
Morgan Park[13]	1,046			45	Water at 1,040 feet.
New Chicago	1,309				
Oakpark	1,558				
Do	1,568	6¼	500	−20	Water from 1,529 feet.
Do	2,200			- 20	Water from 1,600 and 2,200 feet.
Palatine[14]	1,656			+ 2	Water at 160 and 800 feet.

[1] U. S. Geol. Surv. Monograph No. 38, 1899, pp. 611-612.
[2] Record, Ill. Geol. Surv., pp. 61, 66.
[3] U. S. Geol. Surv. Monograph No. 38, 1899, p. 711.
[4] Ibid., Folio No. 67.
[5] Ibid., Monograph No. 38, 1899, p. 726.
[6] Ibid., p. 587.
[7] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 810.
[8] Ibid., p. 811.
[9] Record, Economic Geology, Ill., vol. 2, p. 186.
[10] U. S. Geol. Surv. Monograph No. 38, 1899, p. 584.
[11] Ibid., 17th Ann. Rept., 1895–96, part 2, p. 813; analysis, ibid., p. 827; Monograph No. 38, 1899, p. 587.
[12] Ibid., Monograph No. 38, 1899, p. 590.
[13] Ibid., pp. 582–590.
[14] Record, ibid., 17th Ann. Rept., 1895–96, part 2, p. 816; Monograph No. 38, 1899, p. 585.

ILLINOIS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Cook County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Park Ridge	1,500	6–3		−10	
Do	1,425				
Riverdale	434				
River Forest	980				
Riverside[1]	2,200				Several wells at depth.
Do	1,575				
South Chicago	1,300				2 wells.
	1,353				
Summit Yards	1,601				
Turners Junction	3,081				
Winnetka[2]	1,570		150	+ 8	Original head +1
Do	1,900				
Washington Heights	1,308				
West Pullman	1,274				
Cumberland County:					
Greenup	640	2			Mineral water.
Dekalb County:					
Dekalb	800	8–6	Many.	−25	
Do	880	10–8	Many.	−55	
Do.[3]	890	14–6	300	−65	Water 125 to 161 a 890 feet.
Do	981	6–4	Many.	−60	
Do.[3]	700		Many.	−40	
Do.[3]	800–2,470				3 wells.
Malta	800				
Dewitt County:					
Clinton[4]	942				Prospect boring
Douglas County:					
Tuscola	792				
Do	3,000	9–6			Temp., 60°.
Dupage County:					
Bensonville[5]	+2,000				
Hinsdale[6]	864				
Naperville	1,425	12–6¼	140		Water-bearing b and 1,4.5 feet.
West Chicago	869				2 wells.
	2,081				
Edgar County:					
Paris	2,200	8	Not any.		
Do	2,500				
Fayette County:					
Ramsey	+ 400				
Vandalia	574				
Ford County:					
Gibson[6]	705				Boring for coal.
Paxton[6]	2,670		Many.		
Franklin County:					
Benton	780	5	3	12	
West Frankfort	465				Coal prospect.
Fulton County:					
Avon	1,818				
Canton[7]	2,500	4	125	+31	Water from 2,050
Do.[7]	1,646¼	14–6	260	+15	Water from 1,10 feet and 1,403 feet.
Do.[8]	2,333				Unsuccessful.
Ipava[9]	1,570	4	60		Also salty and su water at about
Vermont[10]	3,487				Test boring for etc.; not util water.
Gallatin County:					
Equality	1,800	6–3¼			Very salty water
Shawneetown[11]	1,513				For oil, only s found.
Do.[12]	1,500				At 500 feet, small at 1,500, large salt water.
Greene County:					
Carrollton[13]	1,330			−50	Water from 1,22 feet.

[1] U. S. Geol. Surv. Monograph No. 38, 1899, p. 589.
[2] Analysis, ibid., 17th Ann. Rept., 1895–96, part 2, p. 828; Monograph No. 38, 1899, p. 587.
[3] Ibid., Monograph No. 38, 1899, p. 602.
[4] Partial record, ibid., pp. 705–706.
[5] U. S. Geol. Surv. Monograph No. 38, 1899, p. 592.
[6] Ibid, pp. 662–663.
[7] Record, ibid., 17th Ann. Rept., 1895–96, part 2, p. 849; Monograph No. 38, 1899, p. 687.
[8] Record, Ill. Geol. Surv. Rept., vol. 8, pp. 62–63.
[9] Ibid., 17th Ann. Rept., 1895–96, part Monograph No. 38, 1899, p. 688.
[10] Ibid., Monograph No. 38, 1899, p. 688
[11] Ibid., 17th Ann. Rept., 1895–96, part
[12] Ky. Geol. Surv. Rept., Petroleum, Gas, etc., by E. Orton, p. 205.
[13] Record, U. S. Geol. Surv., 17th An 1895–96, part 2, p. 849; Monograph No. 3 745.

ILLINOIS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Grundy County:					
Carbon Hill[1]	1,900				
Minooka[1]	2,100			+ 46	Strong water vein at 1,985 feet.
Do	1,162				
Morris[2]	406	10	Many.	Flows.	
Do.[2]	600				
Do	601				
Hamilton County:					
McLeansboro	800	8–5½	3½		
Hancock County:					
Carthage[3]	1,800	5–3		− 16	Brackish water at about 750 and 1,000 feet.
Do.[3]	1,000	10–8		− 20	Water at 865 and 975 feet.
Do.[4]	1,787			+ 5	Mineral water.
Do.[5]	975		Many.		Do.
Hamilton	840				
Denver (near)[6]	1,030		Many.	− 40	
Hamilton	680		36	+ 63	Sulphur water; Ringland's Sanitarium.
Riverside[4]	680		35	+ 63	Mineral water.
Do.	1,300 2,200	3	1,000	+ 20	
Warsaw	780–800	4	100	+ 65	3 wells; water sulphurous
Do.[7]	750	6	90	+155	Do.
Do.[7]	860	6	200	+ 62	Original head +98.
Do.	1,600				
Henderson County:					
Stronghurst[8]	1,601			- 30	Test for oil.
Henry County:					
Cambridge	1,329	9–6	74	−146	
Galva	1,470	9–6	50	−178	
Geneseo[9]	2,250	6	190	+ 31?	
Do.	1,354				
Kewanee[10]	1,480	9–6	130	150	Water from 1,000 feet; temp., 65°.
Do.[10]	1,050	7–4	80		2 wells; temp., 65°.
Do.	1,073	12–6	80	- 350	Coal, 3 feet, at 187 feet; water at 415 feet.
Woodhull	1,394				
Iroquois County:					
Danforth[11]	+1,200				No good water supply.
Gilman	1,746		150	− 7	
Onarga (near)[11]	400				Coal boring; no rock encountered.
Sheldon	1,800	10–5	100	− 40	
Jackson County:					
Murphysboro	509	8			Good water at 400 feet; saline water at 450 feet.
Do.[12]	1,800				Well at brewery; flow of salt water at about 1,300 feet.
Jersey County:					
Jerseyville[13]	2,003	12–3	200	100	Water at 1,400 to 1,600 feet.
Jo Daviess County:					
East Dubuque[14]	940	5	420	- 95	
Do.	1,000				
Galena[15]	1,209	8	166	+ 85	
Warren	697, 875				2 wells.
Kane County:					
Aurora[16]	663				
Do.[17]	1,388	8–6	350		
Do.[17]	2,270			+ 60	
Do.[17]	2,255			+ 60	
Do.	2,235–2,250				3 wells.
Do.	1,971				
Do.	1,457				
Batavia	1,279				

[1] U. S. Geol. Surv. Monograph No. 38, 1899, p. 647.
[2] Record, Economic Geol., Ill., vol. 3, pp. 386–387.
[3] Ibid., 17th Ann. Rept., 1895–96, part 2, p. 810; Monograph No. 38, 1899, p. 682.
[4] Record, Ill. Geol. Surv. Rept., vol. 8, pp. 64–65.
[5] Ibid., p. 62.
[6] U. S. Geol. Surv. Monograph No. 38, 1899, p. 684.
[7] Ibid., p. 683.
[8] Ibid., p. 680.
[9] Ibid., 17th Ann. Rept., 1895–96, part 2, p. 813; analysis, p. 827; Monograph No. 38, 1899, p. 623.
[10] Record, ibid., p. 814; analysis, p. 821; Monograph No. 38, 1899, p. 624.
[11] U. S. Geol. Surv. Monograph No. 38, 1899, pp. 657–658.
[12] Ibid., p. 780.
[13] Ibid., 17th Ann. Rept. 1895–96, part 2, p. 814; analysis, ibid., pp. 808, 827; Monograph No. 38, 1899, p. 747.
[14] Ibid., Monograph No. 38, 1899, p. 565.
[15] Ibid., 17th Ann. Rept. 1895–96, part 2, p. 813; analysis, p. 827; Monograph No. 38, 1899, p. 565.
[16] Ibid., p. 810; Monograph No. 38, 1899, p. 599.
[17] Analysis, ibid., p. 820; Monograph No. 38, 1899, p. 599.

ILLINOIS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Kane County—Continued.					
Carpentersville	692 and 2,300				2 wells.
Elburn	1,375				
Geneva	400–2,500				4 wells.
Gray Willow[1]	500				
Elgin[2]	1,400				Water at 487 to 514 feet; sulphur water at 650 to 700 feet.
Do.[3]	1,876			+ 2	Also sulphur water at 650 to 700 feet.
Do.[3]	2,026	6		+ 27	Sulphur water at 650 to 700 feet; soft water at 2,024 feet.
Do.[4]	2,230			− 4	Also sulphur water at 650 to 700 feet.
Kankakee County:					
Kankakee[5]	1,000	4		− 15	Water from 900 feet.
Kendall County:					
Plattville (2 miles north of).[6]	550			No flow.	Large amount of water.
Knox County:					
Galesburg[7]	1,236				City water works well No. 2.
Do.[8]	1,226	14–6	120	−102	Water at 1,060 to 1,226 feet; temp., 60° F.
Do	1,999				
Knoxville[9]	1,350	8	80		Water from 1,180 to 1,350 feet; temp., 68° F.
Lake County:					
Highland Park[10]	2,200	8–5	150	+ 9	Water at 900, 1,300, 1,700 to 2,200 feet; slightly saline and hard.
Do.[11]	1,800 and over.				3 wells.
Lake Forest[12]	960		60	+ 50	
Do	1,200 1,757				2 wells.
Waukegan[11]	1,135 1,600 2,005				Irony water; 3 wells.
Lasalle County:					
Lasalle[13]	502	6	200		
Marseilles[14]	2,189		1	Flow.	Flow is from 298 feet.
Mendota[15]	400			− 47	
Do.[16]	857			− 14	Flows at 187 and 637 feet.
Do	470–504				3 wells.
Ottawa[17]	400				Has 200 wells 400 feet deep; water from 290 to 400 feet.
Do.[18]	1,840			+177	Water from 1,640 to 1,840 feet.
Pedicord	2,189		8	At surface.	Water from Potsdam 1,845 to 2,143 feet.
Peru[19]	1,360		200	+120	Water at 750 feet also.
Do	2,300				
Do.[20]	1,250		450	+ 85	
Ransom (near)[21]	543				
Seneca[22]	600–650				2 wells.
Do.[23]	680	4		+ 15	Water, which is hard and sulphurous, is from 350 and 380 feet.
Streator	1,115	8–6	130	No flow.	Water-bearing beds at 596, 706, 834, 1,056, and 1,096 feet.

[1] U. S. Geol. Surv. Monograph No. 38, 1899, p. 597.
[2] Ibid., 17th Ann. Rept. 1895–96, part 2, p. 812.
[3] Ibid., p. 812; Monograph No. 38, 1899, p. 595–596.
[4] Ibid., p. 812; analysis, p. 827; Monograph No. 38, 1899, p. 595.
[5] Record, ibid., 17th Ann. Rept. 1895–96, part 2, p. 814, analysis, p. 821; Monograph No. 38, 1899, p. 653.
[6] U. S. Geol. Surv. Monograph No. 38, 1899, p. 644.
[7] Analysis, Am. Inst. Mining Eng. Trans., vol. 27, p. 135.
[8] U. S. Geol. Surv., 17th Ann. Rept. 1895–96, part 2, p. 813; Monograph No. 38, 1899, p. 677.
[9] Ibid., p. 814; Monograph No. 38, 1899, p. 677.
[10] Ibid., p. 813; Monograph No. 38, 1899, p. 580.
[11] Ibid., Monograph No. 38, 1899, p. 580.
[12] Ibid., 17th Ann. Rept. 1895–96, part 2, p. 814; Monograph No. 38, 1899, p. 580.
[13] Ibid., p. 814; Monograph No. 38, 1899, p. 637.
[14] Record, Ill. Geol. Surv., vol. 8, p. 50; U. S. Geol. Surv. Monograph No. 38, 1899, p. 639.
[15] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 815.
[16] Record, Minn. Geol. Surv., 13th Ann. Rept. pp. 55, 56.
[17] U. S. Geol. Surv., 17th Ann. Rept. 1895–96, part 2, p. 816; Monograph No. 38, 1899, p. 638.
[18] Record, ibid., pp. 798, 799; Monograph No. 38, 1899, p. 638.
[19] Analysis, ibid., p. 828; Monograph No. 38, 1899, p. 637.
[20] U. S. Geol. Surv. Monograph No. 38, 1899, p. 637.
[21] Ibid., p. 641.
[22] Ibid., p. 638.
[23] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 817; Monograph No. 38, 1899, p. 638.

ILLINOIS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
asalle County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Streator	773	9–7	94	No flow.	Coal at 223 feet; fire clay at 236 feet.
Do.[1]	2,496			+ 45	Water at 450, 2,170, and 2,496 feet.
Vermilion[2]	1,000		Many.	Flows.	Flows begin at 380 feet; water slightly saline.
ee County:					
Amboy[3]	2,000			+ 3	Temp., 55° to 60°; water at 330, 1,100, and 1,700 feet.
Do	2,012				
Dixon[4]	1,640 1,730 1,810		Many.		3 wells.
Do	1,500–1,800				5 wells.
Pawpaw[5]	1,018				
Sublette	752				
ivingston County:					
Chatsworth[6]	1,200			− 25	
Fairbury[7]	2,002				
Do.[8]	571				Water at 427 feet.
Do	2,002	8		− 60	
[c Donough County:					
Macomb	1,350			− 55	
Do.[9]	1,630				Water from 1,135 to 1,360 feet.
[c Henry County:					
Algonquin[10]	2,527				Bad water; abandoned.
Harvard[11]	900	12–7	90	− 41	Hard water.
Woodstock[12]	1,014	6¼	500	− 60	
Do	410	5		−130	
Do	957				
acon County:					
Decatur[13]	507				
adison County:					
Alton	890	6–4	35–40	Flows.	2 wells; mineral water.
Bethalto	1,000	12	15	− 25	Saline water.
Collinsville[14]	575 600			—120	2 wells; water slightly saline.
ar ion County:					
Centralia[15]	864	6			Unsuccessful.
ar shall County					
Henry[16]	1,300	3¼	32		White sulphur water.
Wenona[16]	1,854		100	− 25	
ercer County:					
Aledo[17]	3,115		Many.	− 75	Water at 1,200 feet; salty water from 2,300 to 2,620 and 3,071 feet.
Wanlock	1,247				
Monroe County:					
Columbia[18]	1,010	5¼		− 10	Water not pleasant.
Waterloo	1,036	9¼–7¼	20		20-gallon flow at 80 feet also; temp., 50°.
Montgomery County:					
Litchfield[19]	682				Oil with salt water and gas.
Morgan County:					
Alexander (near)[20]	1,000				
Franklin	1,200				Flow for gas unsuccessful.
Jacksonville[21]	1,600				For gas.
Do.[22]	2,373	6–4¼	30	+ 15	Water brackish at 2,310 feet.
Do.[22]	2,408	5¼	85	+ 10	Water brackish at about 2,100 feet.
Do.[22]	3,028	6¼–5¼	500	+ 30	Water from 1,800 and 3,000 feet; slightly saline.

[1] Ill. Geol. Surv., vol. 7, pp. 50, 59; record, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 798; analysis, p. 821; Monograph No. 38, 1899, p. 639.
[2] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 818; Economic Geol., Ill., vol. 2, p. 235; U. S. Geol. Surv. Monograph No. 38, 1899, p. 639.
[3] Ibid., p. 810; Monograph No. 38, 1899, p. 610.
[4] Analysis, ibid., p. 827; Monograph No. 38, 1899, p. 609.
[5] U. S. Geol. Surv. Monograph No. 38, 1899, p. 611.
[6] Record, Economic Geol., Ill., vol. 3, pp. 595–596.
[7] U. S. Geol. Surv. Monograph No. 38, 1899, p. 666.
[8] Ill. Geol. Surv., vol. 6, p. 242.
[9] Analysis, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, pp. 808, 827; Monograph No. 38, 1899, p. 685.
[10] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 810; Monograph No. 38, 1899, p. 578.
[11] Ibid., Monograph No. 38, 1899, p. 576.
[12] Ibid., p. 577.
[13] Record, Economic Geol., Ill., vol. 3, pp. 538–539.
[14] U. S. Geol. Surv. Monograph No. 38, 1899, p. 749.
[15] Record, Economic Geol., Ill., vol. 2, pp. 138–139.
[16] U. S. Geol. Surv. Monograph No. 38, 1899, p. 669.
[17] Ibid., 17th Ann. Rept., 1895–96, part 2, p. 810; Monograph No. 38, 1899, p. 622.
[18] Ibid., Monograph No. 38, 1899, pp. 765–766.
[19] Record, Ill. Geol. Surv., vol. 7, p. 37; U. S. Geol. Surv. Monograph No. 38, 1899, p. 741.
[20] U. S. Geol. Surv. Monograph No. 38, 1899, p. 724.
[21] Ill. Geol. Surv., vol. 8, p. 67.
[22] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, pt. 2, p. 814; analysis, p. 820; Monograph No. 38, 18 p. 723.

ILLINOIS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Ogle County:					
Mount Morris[1]	502				
Polo	2,098		Many.		
Peoria County:					
Peoria (opposite)[2]	734			+ 60	Sulphur water.
Do	1,800				
Perry County.					
Pinckneyville[3]	2,000				
St. Johns[4]	1,050		6		6 salt wells; brine at 970 feet.
Do.[5]	3,750				Supply of water at 31[illegible] feet, which was soon exhausted; salty water below 520 feet.
Piatt County:					
Monticello	1,100				Flow of mineral water also.
Pike County:					
Barry[6]	2,510	6	100	− 35	
Pittsfield[7]	2,200				
Putnam County:					
Hennepin[8]	800	4	80	+ 50	Slightly saline water; temp., 58°.
Randolph County:					
Coulterville[9]	1,117				Water brackish.
Do	1,201				No gas or oil found.
Redbud[10]	580	3	4	+ 7	
Do.[10]	1,350	4		− 20	
Sparta[11]	480			− 75	
Do.[9]	840–864				Several borings, furnishing a supply of gas.
Richland County:					
Olney[12]	2,000			No flow.	Saline water.
Do	2,200				
Rock Island County:					
Carbon Cliff[13]	915	5½	400	+ 50	Brackish water at 850 feet.
Do.[14]	950				
Do	909				
East Moline	1,340	6	240	+ 36	750 and 1,030 to 1,080 feet.
Milan[15]	1,217				
Do.[16]	1,157	8–5	318	+ 61	Water from 800 and 1,0[illegible] feet.
Do	1,221				
Moline[17]	1,166		250	− 25	
Do.[18]	1,628	5	350	+ 82	Sulphur water at about 700 feet.
Do	1,700 2,368				2 wells.
Port Byron Junction	1,340				
Rock Island[19]	1,150	4	400	+ 70	Sulphur water at 750 and 980 feet.
Do.[20]	2,282	8–4½		+ 50	Also sulphur water at 800 feet.
Do	1,068–2,292				3 wells.
St. Clair County:					
Belleville	503			− 80	
Do	432, 569				
East St. Louis	1,100				Good drinking water, but unfit for boilers.
Marissa	685		35	No flow.	
Mascoutah	3,053				
Millstadt[21]	620	7½	4	− 75	Hard water.
Saline County:					
Eldorado	520	3½	Few.		
Sangamon County.					
Divernon	604		Not any.		Coal prospect.
Riverton[22]	2,584				No gas, oil, or water found.
Springfield[23]	Nearly 1,200			No flow	

[1] U. S. Geol. Surv., Monograph No. 38, 1899, p. 605.
[2] Economic Geol., Ill., vol. 2, p. 449.
[3] U. S. Geol. Surv. Monograph No. 38, 1899, p. 771.
[4] Ill. Geol. Surv., vol. 7, p. 38.
[5] Partial record, etc., U. S. Geol. Surv. Monograph No. 38, 1899, pp. 772–773.
[6] Analysis, ibid., 17th Ann. Rept., 1895–96, part 2, p. 827. Monograph No. 38, 1899, p. 719.
[7] U. S. Geol. Surv. Monograph No. 38, 1899, p. 721.
[8] Ibid., p. 634.
[9] Ibid., p. 769.
[10] Ibid., p. 768.
[11] Ibid., 17th Ann. Rept., 1895–96, part 2, p. 817.
[12] Ill. Geol. Surv. Rept., vol. 7, p. 8. U. S. Geol. Surv. Monograph No. 38, 1899, p. 757.
[13] Record, ibid., vol. 8, pp. 64–65.
[14] Record, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part. p. 849.
[15] U. S. Geol. Surv. 17th Ann. Rept., 1895–96, part 2, p. 846.
[16] Ibid., p. 815, analysis, pp. 808, 827; Monograph No. 38, 1899, p. 621.
[17] Record, ibid., pp. 847, 848.
[18] Ibid., p. 848, analysis, pp. 808, 827.
[19] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 816, analysis, pp. 808, 828, record, pp. 845–846.
[20] Ibid., pp. 817, 845.
[21] Ibid., Monograph No. 38, 1899, p. 762.
[22] Ill. Geol. Surv. Reports, vol. 8, p. 62.
[23] Ibid., vol. 5, p. 312.

ILLINOIS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bureau County:					
Bureau[1]	2,500				Water has unpleasant taste; discontinued.
Cass County:					
Virginia[2]	412			+ 25	Water from 350 feet.
Clay County:					
Flora	1,200	6		Flows.	Water is saline, and from 625 feet.
Clinton County:					
Carlyle	704				
Coles County:					
Mattoon	2,454	8-6	Many.	−175	
Cook County:					
Chicago	734				Brackish water at 317 and 734 feet.
Cook County:					
Chicago[3]	850				Salt at 500 feet.
Do	1,000	6	167	+ 65	Salt water at 425 feet; lower water strongly sulphurous; temp., 70°.
Cook County:					
Chicago Heights	1,308				
Cook County:					
Chicago[4]	1,149				
Cook County:					
Chicago Junction[5]	2,008				Brackish water at 1,700 to 1,735 feet.
Cook County:					
Rossville[6]	500				Coal boring.
Edgar County:					
Lancaster[7]	+800	6			For oil; unsuccessful.
Mount Carmel[8]	700				Bored for oil.
Edwards County:					
Alexis	1,200				
Monmouth[9]	1,232				No flow water; no gas; no oil.
Do	1,400	6-4	210	60	
Do.[10]	1,230		200	60	Water from 1,074 to 1,230 feet.
Do.[11]	1,227			− 60	Water at 935 and from 1,074 to 1,227 feet; two wells.
Do	1,221				
Roseville	1,260				
Fayette County:					
Carmi	600		Many.	Flows.	
Fayette County:					
Fulton[12]	1,246	5	300	+ 61	First flow, 475 feet; sulphur water.
Do	1,214				
Morrison[13]	1,190			+ 15	Well not in use.
Sterling[14]	1,450		350	At surface.	
Do	1,500				
Will County:					
Braidwood[15]	900	4		At surface.	Water from a porous sandstone at 655 to 855 feet, the lower 45 feet being in limestone.
Joilet[16]	477		Many.	Flows.	
Do.[17]	1,200		500		2 wells.
Do.[18]	1,700		500	+ 10	Temp., 45°.
Do.[19]	2,076			+ 10	
Do	2,300				
Do	1,196–2,140				5 wells.
Do.[15]	1,948				State penitentiary.
	553				
Lockport	1,921				
Wilmington[20]	635	4½		46	Sulphurous and magnesia water from 400 to 635 feet.

[1] U. S. Geol. Surv. Monograph No. 38, 1899, p. 712.
[2] Ibid., p. 722.
[3] Ibid., p. 691.
[4] Record, U. S. Geol. Surv. Folio No. 67.
[5] Ibid., Monograph No. 38, 1899, p. 699, record, U. S. Geol. Surv. Folio No. 67.
[6] Ibid., p. 699
[7] Record, Economic Geol., Ill., vol. 3, pp. 58-60.
[8] Record in part, ibid., vol. 3, pp. 386-387.
[9] Record, Ill. Geol. Surv. Rept., vol. 8, pp. 62-66.
[10] Record, U. S. Geol. Surv., 17th Ann. Rept., 1895-96, part 2, p. 848, analysis, pp. 808, 827.
[11] Ibid., p. 848; analysis, pp. 808, 827. Monograph No. 38, 1899, p. 678.
[12] U. S. Geol. Surv. 17th Ann. Rept., 1895-96, part 2, p. 813; Monograph No. 38, 1899, p. 615.
[13] Ibid., Monograph No. 38, 1899, p. 616.
[14] Analysis, U. S. Geol. Surv., 17th Ann. Rept., 1895-96, part 2, p. 828, Monograph No. 38, 1899, p. 616-617.
[15] U. S. Geol. Surv. Monograph No. 38, 1899, p. 650.
[16] Record, Economic Geol., Ill., vol. 2, pp. 482, 487, U. S. Geol. Surv. Monograph No. 38, 1899, p. 649.
[17] U. S. Geol. Surv. Monograph No. 38, 1899, p. 649.
[18] Ibid., 17th Ann. Rept., 1895-96, part 2, p. 814; analysis, p. 821.
[19] Record, ibid., pp. 799, 814, Monograph No. 38, 1899, p. 650.
[20] Ibid., 17th Ann. Rept., 1895-96, part 2, p. 818; Monograph No. 38, 1899, p. 650.

ILLINOIS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Williamson County:					
Marion	1,715	.....	.....	Flow.	For gas and oil; sulphurous and salt water found.
Winnebago County:					
Harlem	1,047	.....	.....	.....	
Rockford [1]	1,300–1,996	8–6	116–260	+ 8	5 wells; water from 3[illegible]0 to 400 feet and 1,200 to [illegible],300 feet.
Do. [2]	400	6	.....	− 8	
Woodford County:					
Minonk [3]	1,755	.....	100	−149	Moderately hard water at 750 feet and at about 1,700 feet.
Potsdam	1,500	.....	Many.	.....	
Review	1,400	6	.....	.....	Temp., 62°.
Do.	1,233	.....	208	54	Salt water from 600 to 1,[illegible] feet.

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 816, analysis, p. 828.
[2] Analysis, ibid., p. 828.
[3] U. S. Geol. Surv. Monograph No. 38, 1899, p. 6[illegible]

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN ILLINOIS.

Illinois Geological Survey, Reports on Geology and Palæontology, volumes 5, 187[illegible] 6, 1875; 7, 1883, and 8, 1890.

Economical Geology of Illinois, by State geologist, volumes 2 and 3, Springfield [illegible] 1882.

The water resources of Illinois, by Frank Leverett: United States Geological Survey Seventeenth Annual Report, 1895–96, part 2, pp. 695–849, plates, Washington [illegible] 1896.

Wells of Illinois, by Frank Leverett: United States Geological Survey Monograph No. 38, 1899, pages 550–787.

U. S. Geol. Surv. Folio No. 67 (Illinois-Indiana), by M. R. Campbell and Frank Leverett, Washington, 1900.

INDIANA.

The numerous deep borings in Indiana are for oil or gas, but a few of them yield water supplies. The wells are in groups or "districts," often many square miles in extent. Where localities given in the following list are in districts, only representative wells are described, for it would not be practicable here to list all the individual wells. In some localities new wells are constantly being sunk.

Location	Depth	Diameter	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Adams County					
Decatur [illegible]	1,[illegible]00	.....	.....	.....	For gas; unsuccessful; salt water.
Allen County					
Fort Wayne [illegible]	250–[illegible]00	.....	5,000 in all.	−6 [illegible]	[illegible] wells at waterworks.
Fort Wayne [illegible]	1,458	.....	.....	.....	For gas, unsuccessful.
Fort Wayne [illegible]	1,[illegible]00	.....	.....	−90	For gas; unsuccessful; mineral water.
Fort Wayne [illegible]	[illegible]00	.....	.....	[illegible]	For gas, unsuccessful.
Bartholomew County					
Columbus [illegible]	1,[illegible]0	.....	.....	.....	Gas well.
Elizabethtown [illegible]	[illegible]4	.....	.....	.....	Do.
Hartsville [illegible]	[illegible]	.....	.....	.....	Do.

[1] Record, U. S. Geol. Surv., 17th Ann. Rept., 1889–90, part [illegible]
[2] Analysis, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part [illegible], p. 828.
[3] Record, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 4, p. 72. 18th Ann. Rept., 1896–97, part 4, [illegible]
[4] Analysis, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 4, p. 72. 18th Ann. Rept., 1896–97, part 4, [illegible]

INDIANA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Benton County:					
Earl Park	1,000	5			Abandoned.
Oxford (5 miles southwest).	537				
Blackford County:					
Hartford City[1]	900–1,000				Over 1,000 wells for oil and gas in the county.
Montpelier[2]	975			Flows.	Gas well; hard water.
Do	808				
Boone County:					
Lebanon[3]	1,350–1,840				Several wells; saline water at 400 and 1,350 feet.
Thorntown	1,500	6	5	Flows.	For gas; unsuccessful.
Zionsville[3]	1,038			−438	For gas; unsuccessful; salt water at 1,013 feet.
Do	800			Flows.	For gas; unsuccessful.
Brown County:					
Nashville	500–530			Flows.	2 wells.
Carroll County:					
Deer Creek (one-half mile south).	± 840	6–4			Oil at 825 feet; salt or mineral water at 833 feet.
Delphi[4]	914				For gas; unsuccessful.
Do	1,200				
Delphi (2 miles southwest).[5]	923	6–4			Salt or mineral water at 923 feet.
Delphi (northeast)	928	6–4			Salt or mineral water at 928 feet; also oil.
Delphi (southeast, at water tower).	947	6–4		Flows.	Salt or mineral water at 922 feet; also oil and gas.
Delphi (southeast)	1,315	6–4		Flows.	Salt or mineral water at 898 feet; also oil and gas.
Delphi (northwest)	1,385	6–4			Salt or mineral water at 923 feet.
Flora	±1,100	6–4			Salt water at 1,040 feet; also oil.
Cass County:					
Galveston[6]	860				
Do	934				Salt water only.
Logansport[7]	+1,075		2	Flows.	Several boring for gas; unsuccessful; sulphur water.
Do	1,600				
Royal Center[8]	+ 925				Oil wells.
Walton	1,028				Salt water and some oil.
Clark County:					
Jeffersonville[9]	960–1,216				For gas; unsuccessful.
Clay County:					
Carbon (2 miles south)	936				Not successful.
Do	1,255	10		− 40	Good water at 350 feet.
Clinton County:					
Frankfort[3]	1,446			−600	Salt water at 1,200 feet.
Frankfort (4 miles east)	1,105				For gas; unsuccessful.
Kirklin	1,088				Do.
Crawford County:					
English (8 miles south)	700	3	11	+ 35	
Do	887	8	8	+ 50	
English, Clark well[10]	648				Gas at 408 feet; salt water at 648 feet; some oil.
Mifflin[11]	1,180				Some oil at 135 feet and some gas at 1,180 feet.
Dearborn County:					
Aurora[12]	1,000				Brackish water at 195 feet, brine at 831 feet, and gas at 267 feet.
Lawrenceburg					Gas wells.
Decatur County:					
Adams	± 800				Do.
Greensburg[13]	862–886				Numerous gas wells.
Millhousen	1,000–1,100	6			Several gas wells.
St. Omer					Gas well.
Sandusky	830	6		− 15	

[1] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 678–681.
[2] Ibid., p. 680.
[3] Ibid., p. 730.
[4] Ibid., p. 731.
[5] Record, Mich. Geol. Surv., 1881–1893, p. 54, pl. 14.
[6] Record, Ind. Geol. and Nat. Hist. Surv., 19th Ann. Rept., 1894, p. 39.
[7] Ibid., p. 38; U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 732.
[8] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 732.
[9] Record, Ibid., p. 724.
[10] Record, Ind. Geol. and Nat. Hist. Surv., 17th Ann. Rept., 1891, p. 311.
[11] Ibid., pp. 311–312.
[12] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 705.
[13] Ibid., pp. 703–704.

INDIANA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons*	*Feet.*	
Dekalb County:					
Auburn	+1,933				Gas wells.
Butler	600				Hard water.
Do.[1]	2,139				For gas, unsuccessful; salt water.
Garrett					Small gas well.
Waterloo					Gas well.
Delaware County:					
Albany[2]	978				Do.
Do	1,262	8-6½			Oil in small quantity.
Cowan	+ 935				Gas well.
Daleville	+ 870				Do.
Desoto					Do.
Eaton[3]					Do.
Muncie[4]	870-955				Numerous wells in vicinity.
Do.[5]	1,606			-506	Brine at 1,390 feet.
Do	1,243				Oil.
New Corner					Gas well.
Oakville					Do.
Royerton					Do.
Selma[6]	1,025				Do.
Shideler					Do.
Union Grove	944				Do.
Yorktown	940				Do.
Dubois County:					
Jasper	1,100	8			Salt water at 460 feet, gas at 600 feet, oil and mineral water at 955 feet.
Elkhart County:					
Elkhart[7]	+ 615	5½		Flowed.	For gas; unsuccessful; salt water at 550 feet.
Goshen[8]	2,059			Flows.	For gas; unsuccessful; salt water.
Fayette County:					
Connorsville[9]	851	8			Gas well.
Floyd County:					
Boone Landing					Gas wells.
New Albany					For gas; unsuccessful.
Tobasso Landing					Gas wells.
Fountain County:					
Attica	900			Flows.	Sulphurous water.
Covington (3 miles below).	1,000				
Lodi[10]	1,155	10	35	+43	For oil; yields mineral water.
Franklin County:					
Brookville (4 miles south).[11]	1,254				Gas wells.
Mount Carmel (1 mile west).[12]	590				
Fulton County:					
Fulton	1,150				Salt water only; abandoned.
Kewanna[13]	1,089			-84	For gas; unsuccessful.
Rochester[13]	1,185				Do.
Do	500		Many.	+ 5	Sulphur water.
Rochester (1½ miles south).	1,157			-15	Salt water at 1,157 feet.
Rochester	1,500				Water flowed at 240 feet; well abandoned.
Gibson County:					
Fort Branch[14]	408				
Princeton	600-790				Several wells.
Do	1,274				
Do.[14]	422-1,020				Do.
Grant County:					
Fairmount[15]	500-1,000	8-4			Gas wells.
Herbst station	1,045				Gas well.
Jonesboro[16]	935				Do.
Marion[17]	+865-1,010	4		Flow.	Numerous gas wells; some yield oil.
Point Gabel					Gas well.

[1] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 738.
[2] Ibid., p. 715.
[3] Ibid., p. 713.
[4] Ibid., pp. 713-719.
[5] Ibid., p. 731.
[6] Ibid., pp. 715-716.
[7] Ibid., p. 735. Mich. Geol. Surv., 1881-1893, p. 57, pl. 17.
[8] U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 735. Mich. Geol. Surv., 1881-1893, p. 60, pl. 19.
[9] Ibid, p. 721.
[10] Record, Ind. Geol. Surv., 1st Ann. Rept., 186[illegible] pp. 29-31.
[11] Record, U. S. Geol. Surv., 11th Ann. Rept 1889-90, part 1, p. 707.
[12] Ibid., Folio No. 105, 1904 p. 8.
[13] Ibid., 11th Ann. Rept., 1889-90, part 1, p. 733.
[14] U. S. Geol. Surv. Folio No. 105, 1904, p. 8.
[15] Record, ibid., 11th Ann. Rept., 1889-90, part [illegible] p. 685
[16] Ibid., p. 688.
[17] Ibid., pp. 685-687.

INDIANA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Benton County:					
Earl Park	1,000	5			Abandoned.
Oxford (5 miles southwest).	537				
Blackford County:					
Hartford City [1]	900–1,000				Over 1,000 wells for oil and gas in the county.
Montpelier [2]	975			Flows.	Gas well; hard water.
Do	808				
Boone County:					
Lebanon [3]	1,350–1,840				Several wells; saline water at 400 and 1,350 feet.
Thorntown	1,500	6	5	Flows.	For gas; unsuccessful.
Zionsville [3]	1,038			−438	For gas; unsuccessful; salt water at 1,013 feet.
Do	800			Flows.	For gas; unsuccessful.
Brown County:					
Nashville	500–530			Flows.	2 wells.
Carroll County:					
Deer Creek (one-half mile south).	+ 840	6–4			Oil at 825 feet; salt or mineral water at 833 feet.
Delphi [4]	914				For gas; unsuccessful.
Do	1,200				
Delphi (2 miles southwest). [5]	923	6–4			Salt or mineral water at 923 feet.
Delphi (northeast)	928	6–4			Salt or mineral water at 928 feet; also oil.
Delphi (southeast, at water tower).	947	6–4		Flows.	Salt or mineral water at 922 feet; also oil and gas.
Delphi (southeast)	1,315	6–4		Flows.	Salt or mineral water at 898 feet; also oil and gas.
Delphi (northwest)	1,385	6–4			Salt or mineral water at 923 feet.
Flora	±1,100	6–4			Salt water at 1,040 feet; also oil.
Cass County:					
Galveston [6]	860				
Do	934				Salt water only.
Logansport [7]	+1,075		2	Flows.	Several boring for gas; unsuccessful; sulphur water.
Do	1,600				
Royal Center [8]	+ 925				Oil wells.
Walton	1,028				Salt water and some oil.
Clark County:					
Jeffersonville [9]	960–1,216				For gas; unsuccessful.
Clay County:					
Carbon (2 miles south)	936				Not successful.
Do	1,255	10		− 40	Good water at 350 feet.
Clinton County:					
Frankfort [3]	1,446			−600	Salt water at 1,200 feet.
Frankfort (4 miles east)	1,105				For gas; unsuccessful.
Kirklin	1,088				Do.
Crawford County:					
English (8 miles south)	700	3	11	+ 35	
Do	887	8	8	+ 50	
English, Clark well [10]	648				Gas at 408 feet; salt water at 648 feet; some oil.
Mifflin [11]	1,180				Some oil at 135 feet and some gas at 1,180 feet.
Dearborn County:					
Aurora [12]	1,000				Brackish water at 195 feet, brine at 831 feet, and gas at 267 feet.
Lawrenceburg					Gas wells.
Decatur County:					
Adams	± 800				Do.
Greensburg [13]	862–886				Numerous gas wells.
Millhousen	1,000–1,100	6			Several gas wells.
St. Omer					Gas well.
Sandusky	830	6		− 15	

[1] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 678–681.
[2] Ibid., p. 680.
[3] Ibid., p. 730.
[4] Ibid., p. 731.
[5] Record, Mich. Geol. Surv., 1881–1893, p. 54, pl. 14.
[6] Record, Ind. Geol. and Nat. Hist. Surv., 19th Ann. Rept., 1894, p. 39.
[7] Ibid., p. 38; U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 732.
[8] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 732.
[9] Record, ibid., p. 724.
[10] Record, Ind. Geol. and Nat. Hist. Surv., 17th Ann. Rept., 1891, p. 311.
[11] Ibid., pp. 311–312.
[12] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 705.
[13] Ibid., pp. 703–704.

INDIANA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Jackson County—Cont'd.					
Seymour[1]	1,090-1,204			Flows.	Several gas wells.
Do.	500				Sulphur water.
Jasper County:					
Rensselaer	800				Do.
Do.	1,275				Gas boring; not in us
Jay County:					
Bryant	1,050				Oil well; abandoned.
Camden					Gas wells.
Como					Gas well.
Dunkirk	± 925				Do.
Hartford	± 925				Do.
Millgrove	± 925				Do.
Portland[2]	900-1,500			−300	Gas wells; salt wat 1,500 feet.
Red Key	+ 900				Gas well.
Do.	1,385	8-6			Oil; gas at 960 feet.
Jefferson County:					
Madison[3]	1,004			−700	For gas; unsuccessfu
North Madison	1,500	6	Many.	−200	
Jennings County:					
North Vernon[3]	±1,460			+260	Gas boring; unsucce salt water.
Vernon	928				For gas; unsuccessfu
Johnson County:					
Edinburg[4]	1,583			− 83	For gas; salt water o
Franklin[5]	1,113				Gas well.
Greenwood	600			− 45	Water from 320 feet.
Do.[4]	1,975			−240	For gas; unsucce water at 1,840 and feet.
Trafalgar	1,500				Dry well.
Kosciusko County:					
Leesburg	1,800	5			
Warsaw[6]	700		15		For gas; unsuccessful
Do.[7]	1,437			-387	Salt water.
Lake County:					
Crown Point[8]	1,365			−120	For gas; unsucc Salt water.
Do.[9]	3,100				Not successful.
Hammond	1,842 1,917				2 wells.
Do.	1,700-1,900				Several wells.
Hartsdale	735				
Laporte County:					
Lacrosse (3 miles distant).	838			At surface.	Good water.
Laporte					For gas; unsuccessfu
Michigan City	819-833		300	+ 22	Temp., 57°. Sulphu ter.
Michigan City (1 mile west).[10]	541				
Lawrence County:					
Bedford	1,050				
Mitchell	+1,200			− 30	For gas; saline wa 1,200 feet.
Madison County:					
Alexandria	881				Gas wells.
Anderson[11]	800				Water, mineral; cit ply in part.
Do.[12]	800-900	8		− 25	Gas wells in vicinity
Chesterfield[13]	948				Gas well.
Elwood	± 936				Do.
Florida					Do.
Frankton	840				Do.
Huntsville					Do.
Lapelle					Do.
Markleville	972				Do.
Pendleton[14]					
Perkinsville					Do.
Summitville					
Do.	1,000	8-6		At surface.	
Do.[15]	971			Flows.	Gas well; water at 14

[1] U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, pp. 726-727.
[2] Record, ibid., p. 681.
[3] Ibid., p. 723.
[4] Ibid., p. 728.
[5] Ibid., p. 727.
[6] Ibid., p. 739.
[7] Ibid., p. 736.
[8] Ibid., p. 734.
[9] Borings preserved in county auditor's office.
[10] Record, Ind. Geol. and Nat. Hist. Surv Ann. Rept., 1891, p. 315; U. S. Geol. Surv. Ann. Rept., 1896-97, part 4, p. 491.
[11] U. S. Geol. Surv., 18th Ann. Rept., 1896-9 4, p. 487.
[12] Record, ibid., 11th Ann. Rept., 1889-90, pp. 711-713.
[13] Ibid., pp. 709-713.
[14] Ibid., p. 710.
[15] Ibid., p. 709.

INDIANA—Continued.

tion.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
::	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
1	1,200				Gas well.
d	455			− 15	Several wells.
	476	8	139	− 60	Railroad well.
	1,181				Some gas, oil, and salt water.
ple	+ 950				Gas wells.
d	+1,039				Salt water.
lis	950–1,039				For gas; unsuccessful.
	1,520				Do.
	990				Gas well.
	1,015			−315	
ty:					
[8]	+1,368			−468	For gas; unsuccessful.
:					
	1,200				
	960			Flows.	Some salt water.
:					
	940				Salt water at 385 feet.
ll[5]	[1] 1,004			− 20	For gas; unsuccessful; salt water.
	200–435				Hard water; brackish water at 435 feet.
	900–950				Gas wells in vicinity.
	900–1,050			To surface.	Boring for oil and gas.
iles north)[8]	1,042			− 50	Salt water at 1,042 feet.
	937				Gas wells; flow of water also.
	936				Do.
y:					
on[10]	2,730				No good water; abandoned.
ounty:					
ville[11]	1,514				For gas; unsuccessful. Sulphur water at 750 feet.
y:					
le	1,472				For gas.
	668–704	5–6	30–35	Flow.	6 wells of mineral water.
	± 500				
e	±1,500				
vn	1,665	8		Nearly to surface.	Gas borings; fresh water at 70 and 490 feet; saline water at 1,100 feet.
y:					
	1,436				
	1,200			60	
	1,325				For gas; unsuccessful.
	1,914				Do.
lle	+1,920				Do.
y:					
	1,000				Sulphur water at 250 feet; salt water at 900 feet; lithia water at 1,000 feet.
	926		Many.	+ 30	White sulphur water.
	1,150	4	200	+ 65	Several wells; saline water.
a	1,675	4	Many.	+115	Water at 450 and 1,100 to 1,200 feet.
	1,700		475	Rises to surface.	Salt water at 300 and 450 feet; sulphur water at 1,200 feet, which rose to + 100 feet.
	2,169				For gas; unsuccessful.
	750	8–5¾		−150	Water and oil.
	1,161				Blue lick water.
	1,200				Gas well.

. S. Geol. Surv., 11th Ann. Rept.,

d. Geol. and Nat. Hist. Surv., 1885–
p. 331.
. S. Geol. Surv., 11th Ann. Rept.,
, p. 735.
d. Geol. and Nat. Hist. Surv., 16th
, 186, 187.
6.
. Surv., 11th Ann. Rept., 1889–90,
691.
d. Geol. and Nat. Hist. Surv., 16th

Ann. Rept., 1888, p. 184; U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 732–733.

[8] Ibid., pp. 185, 255.

[9] Ibid., p. 187.

[10] Ibid., 15th Rept., 1885–86, p. 332.

[11] Record, U. S. Geol. Surv., 11th Ann. Rept., part 1, 1889–90, p. 729.

[12] Record and analysis, ibid., 18th Ann. Rept., 1896–97, part 4, pp. 490, 498.

[13] Record, ibid., 11th Ann. Rept., 1889–90, part 1 p. 737.

INDIANA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks
Pike County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Petersburg (one-half mile east).	1,310			Flows.	Salt water at 600 and 1,310 feet.
Petersburg (2½ miles northeast).	1,200			− 80	Salt water at 600 feet.
Petersburg (one-half mile north).	1,200	10–5½	30	Flows.	Fresh water at 160 feet; salt water at 600 feet; oil at 1,200 feet.
Petersburg (1 mile north)	1,700	10–4		Flows.	Fresh water at 700 feet; some oil at 1,200 feet.
Rogers	1,785	10–4½			
Porter County:					
Furnessville (2 miles northeast).[1]	864		210	+ 18	Several flows; sulphur water at 370 feet.
Hebron					For gas; unsuccessful.
Valparaiso[2]	1,344				Gas well.
Do.[3]	1,336				For gas; unsuccessful.
Pulaski County:					
Francesville	+ 890				Oil and gas; unsuccessful.
Medaryville (6 miles west).[4]	1,030				Salt water and oil.
Winamac	1,200		45	Flows.	For gas; unsuccessful; flow of water also.
Do	1,250				
Putnam County:					
Greencastle	1,200	6			For gas; unsuccessful.
Do	2,000–2,700	8–4		Flow.	Several borings; water at several horizons.
Do	2,750				
Reelsville (near)	2,600		Many.	Flows.	Sulphur water; no oil; temperature, 60°.
Do.[5]	1,240			+ 20	Salt and sulphur water.
Randolph County:					
Farmland[6]	1,017				Gas well.
Losantville	1,105				For gas; unsuccessful.
Parker (1 mile north)					Sulphur water at 250 feet; salt water at 900 feet; lithia water at 1,000 feet.
Ridgeville	981–1,105				Gas borings; unsuccessful.
Union City[7]	1,093–1,780				Several borings for gas; unsuccessful.
Winchester[8]	1,000–1,071				Several gas wells.
Ripley County:					
Osgood	950	5			Gas boring; small supply.
Pierceville	965				For gas; unsuccessful.
Rush County:					
Carthage[9]					Gas near 1,257 feet.
Glenwood	+ 950				For gas; unsuccessful.
Milroy					Do.
Rushville and vicinity[10]					Gas wells.
St. Joseph County:					
South Bend[11]	1,670				For gas; unsuccessful.
Do	2,000				
Shelby County:					
Morristown[12]	921			421	Gas well; much salt water.
St. Paul	+ 820				Gas well.
Shelbyville[13]					For gas; unsuccessful.
Waldron	+ 820				Gas well.
Spencer County:					
Rockport	+ 400				4 gas borings, no product.
Starke County:					
Knox	+ 1,500				Borings for gas or oil, unsuccessful.
Sullivan County:					
Sullivan	1,000			15	Gas boring; much strong brine.
Sullivan (2 miles southeast).	+ 1,000			Flows.	
Sullivan[14]	544				
Tippecanoe County:					
Lafayette[15]	410				
Do	1,000				Gas well.

[1] Record, U. S. Geol. Surv., Water-Sup and Irr. Paper No. 21, p. 16, 1899.
[2] Ibid., 11th Ann. Rept., 1889–90, part 1, p. 733.
[3] Record, Ind. Geol. and Nat. Hist. Surv., 16th Ann. Rept., 1888, p. 264.
[4] Ibid., 17th Ann. Rept., 1891, p. 315.
[5] Record, Ind. Geol. Surv., 1st Ann. Rept., 1869, pp. 29–31.
[6] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 688–689.
[7] Record, ibid., p. 684.
[8] Ibid., pp. 683–685.
[9] Ibid., p. 704.
[10] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 704.
[11] Record, Mich. Geol. Surv., 1881–1893, p. 84, pl. 64, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 734–735.
[12] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 703.
[13] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 702–703.
[14] Record, Ind. Geol. Surv., 1870, pp. 193–194.
[15] Ind. Geol. and Nat. Hist. Surv., 1885–86, 15th Ann. Rept., pp. 69–71.

INDIANA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
ipton County:					
Circleville	+1,078				For gas; unsuccessful.
Kempton[1]	1,035				
Sharpsville[1]	970				For gas; fine flow.
Tipton[2]	1,030				Small amount of gas.
Windfall	1,002				Gas well.
nion County:					
Liberty[3]	971	8–10			For gas; unsuccessful.
Liberty (8 miles from)	1,000	8–10			Do.
anderburg County:					
Evansville	1,100				Several wells; brackish water.
Do.[4]	1,829				Salt water at 1,400 feet.
Do	1,500				
Do	1,215				
igo County:					
Fontanet	+ 400	8		− 12	
Fontanet (one-half mile southwest).	440		Many.		
Fontanet (3 miles southwest).	1,451	8–4	Many.		Water at 400 feet.
Heckland	1,615				
St. Marys	2,055	8		− 75	
Do	830	8		− 75	
Terre Haute[5]	2,800	8		Flows.	Sulphur water with little gas.
Do.[6]	1,793				Brine at 1,300 feet; sulphur water at 1,793 feet; some oil at 1,629 feet.
Do	+1,625				Several borings for oil; unsuccessful.
Do	1,772				
abash County:					
La Fontaine[7]	920				Gas well.
North Manchester[8]	+1,180			−190	Gas boring; unsuccessful; salt water.
Somerset[9]	853				Water at 485 feet.
Treaty	950	8–5			
Do.[10]	900	8–6		+ 8	
Wabash[11]	2,270	6		− 40	For gas; unsuccessful.
arren County:					
Williamsport	1,200			Flows.	Gas well; salt and fresh water also.
arrick County:					
Boonville	1,400			No flow.	Gas well.
Boonville (4 miles west)	1,500	10 or 12		No flow.	
Boonville	1,200	12		Flows.	Salt water.
Chandler	1,505				2 flows of salt water and some gas.
Newburg	400				
Washington County:					
Salem[12]	1,800				For gas; unsuccessful.
Do	750				Gas well.
Wayne County:					
Cambridge	+ 886				For gas; unsuccessful.
Centerville	+ 886				Do.
Dalton	+ 960				Do.
Dublin	1,250			−250	Gas well.
Fountain City	+1,025				For gas; unsuccessful.
Hagerstown	766–1,025				Several gas wells.
Richmond	945				Gas boring, unsuccessful.
Walnut Level	+867				For gas, unsuccessful.
Washington	+976				Do.
Wells County:					
Bluffton	100–500				Hard water.
Do.[13]	1,200				For gas; unsuccessful; salt water.

[1] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 696.
[2] Record, ibid., pp. 695–697. Ind. Geol. and Nat. Hist. Surv., 1885–86 15th Rept., p. 330.
[3] Record, etc., ibid., pp. 720–721.
[4] Ky. Geol. Surv., Petroleum, Gas etc., by Orton, pp. 197–198.
[5] Record, Ind. Geol. Surv., 1870, pp. 126–131.
[6] Ibid., p. 126, Ind. Geol. Surv., 1869, pp. 28–29 31. Am. Jour. Sci., 2d ser., vol. 48, p. 271.
[7] Record, etc., U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 689–690.
[8] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 739.
[9] Record, Ind. Geol. and Nat. Hist. Surv., 17th Ann. Rept., 1891 pp. 252–253.
[10] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, p. 714.
[11] Ind. Geol. and Nat. Hist. Surv. Rept., 1875, pp. 13–48.
[12] U. S. Geol. Surv., 11th Ann. Rept., 1889–90, part 1, pp. 725–726.
[13] Record, ibid., p. 740.

INDIANA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
White County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Monon[1]	±920			Nearly to surface.	Salt water at 880 feet.
Do	+880			Nearly to surface.	Gas boring; salt water at 880 feet.
Monticello	+1,050			−550	Salt water at 1,050 feet.
Monticello[1]	+1,150			−650	For gas; unsuccessful; salt water at 1,150 feet.
Whitley County:					
Columbia City[2]	1,375			− 20	For gas; unsuccessful; salt water.
Larwell[2]	1,593			−200	Do.

[1] Record, U. S. Geol. Surv., 11th Ann. Rept., 1889-90, part 1, p. 731. [2] Ibid., p. 736.

PUBLICATIONS RELATING TO DEEP BORINGS IN INDIANA.

The natural gas field of Indiana, by A. J. Phinney: United States Geological Survey Eleventh Annual Report, 1889–1890, part 1, pp. 579–740, plates, Washington, 1891.

Water resources of Indiana and Ohio, by Frank Leverett: United States Geological Survey Eighteenth Annual Report, 1896–1897, part 4, pp. 423–559, plates, Washington, 1897.

Wells of northern Indiana, by Frank Leverett: United States Geological Survey, Water Supply and Irrigation Papers Nos. 21 and 26, 1899.

INDIAN TERRITORY.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Cherokee Nation:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Bartlesville	1,700				Oil at 1,286 feet.
Bartlesville (2 miles distant).	1,800		Few.	Flows.	Small quantity crude petroleum.
Chelsea (5 miles west)	300–600	8			Several oil wells.
Salina (1¼ miles southeast).	470			Flows.	Salt water.
Do	520			do	Do.
Creek Nation:					
Redfork	1,487				Incomplete; promises large oil field.
Sapulpa	1,480	6			Flow of oil; some salt water.
Sapulpa (6 miles north)	1,440	6			Flow of gas at 1,280 feet with 60 pounds pressure; very little water.
Sapulpa	1,550				Gas at 1,250 feet, with pressure of 50 to 60 pounds.
Do	1,560				Oil; salt water.
Tulsa	1,430				Salty water.
Do	1,424				Salty water; fresh at 266 feet.
Do	1,417				Salty water.
Chickasaw Nation:					
Chickasha	876	10			Salt water at 298 feet; no water below; well in progress.
Choctaw Nation:					
Atoka (15 miles west)	1,414				Small indications of oil at 807 feet; oil at 917 feet; much salt water; salt water and oil at 1,235 feet and 1,347 feet; oil and gas at 1,391 feet.
Osage Nation:					
Pawhuska	2,000				Water at 1,145 feet; gas pressure at 2,000 feet prevented further drilling.

IOWA.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
::					
le	800		None.		Abandoned.
d	900		None.		Coal prospect.
	512		None.		
ounty:					
	676 740	6	700	+ 40	2 wells.
[2]	515	8¼		−300	
[3]	577	8		−280	
	487				
ounty:					
le[4]	2,495	12–4	200	−260	
	1,540	14–7	350	−280	
	1,527 2,500				Do.
ty:					
	1,287	6	62	+ 28¼	Temp., 56°.
	1,425	6	50	+ 28	Do.
y:					
	3,016		Many.	−200	
	3,000				
	2,914				
	2,507				
ty:					
a	1,025	8–6¼	148	− 4	Water-bearing beds at 367, 717, and 883 feet.
	1,784				
	1,720		Many.		
ty:					
	620				Failure.
	486		Many.		Coal prospect.
	1,310		do	−160	
r:					
	2,700	8–4¼	do	− 65	
County:					
ty	600	6–4	60	No flow.	3 wells.
	1,200	8	80	do	
	1,473	8–6		− 75	
unty:					
[7]	1,120	12–9	+6	−206	Water-bearing beds at 225, 375, 405, 475, and 535 feet; temp., 60°; water hard
:y:					
	1,953			No flow.	
	800	6	Many.		
	400				
10 miles south)	600	4¼–3¼			Abandoned.
ıty:					
r[10]	1,006	6–3	20	+ 62	Temp., 54°.
	520	6–3		+ 20	Temp., 52°.
[11]	420				
	417	6	70	−212	
	452	6	None.		Abandoned.
ıty:					
[12]	1,035–1,497	10–5	1,736	+ 68	5 wells.
	1,065	5¼		+ 35	
	1,674	8–5	1,500	+ 45	
	1,159 1,175				2 wells.
	1,132				
r:					
ld	1,817				
unty:					
ter[13]	1,870	10–5		− 14	
ounty:					
on	2,430	6–5	70	− 38	
	507	5¼	45	Flows.	
ounty:					
k	700	4	55	300	Temp., 50°.
unty:					
[14]	802	4			Water at surface.
	955	6	340	+ 81	Several wells of about this depth.

owa Geol. Surv. Rept., vol. 6, 1896, p.

89.

02.

ıd analysis, ibid., pp. 326–328.

bid., vol. 3, pp. 192–195.

nd analysis, ibid., vol. 6, 1896, pp.

bid., pp. 336–339.

[8] Ibid., pp. 261–262.

[9] Record and analysis, ibid., pp. 193–195.

[10] Ibid., pp. 185–188.

[11] Iowa Geol. Surv. Rept., vol. 6, 1896, p. 188.

[12] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 811; analysis, p. 827.

[13] Record and analysis, Iowa Geol. Surv. Rept., vol. 6, 1896, pp. 214–219.

[14] Ibid., pp. 208–214.

IOWA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Dubuque County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Dubuque	1,262	6	450		
Do.[1]	1,954	3	40	+ 1	
Do	1,300–1,400	13	2,000	Flow.	2 wells.
Do.[1]	1,765	3	40		
Do.[1]	1,000	5	580	+ 41	Several wells 96 feet.
Do	2,027				
Do	960 1,317				2 wells.
Do	1,927				
Do	1,416				
Do	1,100				
Franklin County:					
Hampton	1,708				
Fremont County:					
Randolph	1,768	8	Many.	No flow.	
Greene County:					
Jefferson	2,021	8–5		−40	
Grundy County:					
Grundy Center	485			−150	
Hamilton County:					
Webster City[2]	1,250	8–6	70	+ 16	
Hancock County:					
Britt[3]	684	7		− 16	
Do	535	4½		−510	
Hardin County:					
Ackley[4]	920				
Harrison County:					
Dunlap[5]	1,535	6½			
Henry County:					
Mount Pleasant[6]	1,125		165	− 30	
Howard County:					
Cresco	1,158				
Ida County:					
Holstein[7]	2,004	8–4		−275	
Iowa County:					
Amana[8]	1,640		100	+ 30	Temp., 60°.
Cono Township[9]	416			Flows.	
Homestead[10]	2,224	10–4		−117	
Jackson County:					
Sabula[11]	973		720	+ 78	
Jasper County:					
Newton[12]	1,400	5	Many.	90	
Jones County:					
Anamosa[13]	2,007	10–5	300	56	
Do	1,734				
Monticello[14]	1,198		175	40	
Keokuk County:					
Sigourney[15]	1,880	6–4½		30	
South English	420	4	None.		Abandoned.
Whatcheer	636				
Kossuth County:					
Algona[16]	1,050			69	
Lee County:					
Fort Madison[17]	689	6	600	+ 20	
Do.[18]	720	6		+ 85	Temp., 55°.
Do.[18]	764	4		+ 20	
Keokuk[19]	710	6	250	+ 85	Temp., 64°; two wells 700 feet dee
Do.[19]	800	6		+ 47	Temp., 50°.
Do.[19]	2,000	12–10	3 wells 1,700	+ 30	Temp., 65°; 3 wells
Do	900				
Do.[19]	2,230	10	300	+ 30	Another well 1,80 water also at 600 feet.
Do	1,987	6–4			
Do	935		Many.	Flow.	
Montrose	850				
Mount Clara[20]	939			10	Formerly flowed 2 lons.

[1] Record and analysis, Iowa Geol. Surv. Rept., vol. 6, 1896, pp. 208–214.
[2] Ibid., pp. 220–222.
[3] Analysis, ibid., p. 195.
[4] Record, ibid., vol. 3, pp. 189–192; vol. 6, pp. 219–220.
[5] Record and analysis, ibid., vol. 6, 1896, pp. 257–259.
[6] Ibid., pp. 320–321.
[7] Record, ibid., p. 222.
[8] Record and analysis, ibid., pp. 286–287.
[9] Iowa Geol. Surv. Rept., vol. 9, 1898, p. 561.
[10] Record and analysis, ibid., vol. 6, pp.
[11] U. S. Geol. Surv., 17th Rept., 1895–96, p. 817.
[12] Record, Iowa Geol. Surv. Rept., vol. 6.
[13] Ibid., pp. 262–265.
[14] Record and analysis, ibid., p. 265.
[15] Record, ibid., pp. 305–308.
[16] Ibid., p. 196.
[17] Record and analysis, ibid., pp. 321–322.
[18] Ibid., pp. 321–322.
[19] Ibid., pp. 323–326.
[20] Ibid., p. 322.

IOWA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Adair County:					
Fontanelle	800		None.		Abandoned.
Greenfield	900		None.		Coal prospect.
Do	512		None.		
Allamakee County:					
Lansing[1]	676 740	6	700	+ 40	2 wells.
Postville[2]	515	8¼		−300	
Waukon[3]	577	8		−290	
Do	487				
Appanoose County:					
Centerville[4]	2,495	12–4	200	−260	
Do[4]	1,540	14–7	350	−290	
Do	1,527 2,500				Do.
Benton County:					
Vinton[5]	1,287	6	62	+ 28¼	Temp., 56°.
Do[6]	1,425	6	50	+ 28	Do.
Boone County:					
Boone	3,016		Many.	−200	
Do	3,000				
Do	2,914				
Ogden	2,507				
Bremer County:					
Frederika	1,025	8–6¼	148	4	Water-bearing beds at 367, 717, and 883 feet.
Sumner	1,784				
Waverly	1,720		Many.		
Carroll County:					
Arcadia	620				Failure.
Cass County:					
Anita	486		Many.		Coal prospect.
Atlantic[7]	1,310		....do...	−160	
Cedar County:					
Tipton[8]	2,700	8–4¼	....do...	− 65	
Cerro Gordo County:					
Mason City	600	6–4	60	No flow.	3 wells.
Do	1,200	8	80	.....do....	
Do[9]	1,473	8–6		− 75	
Cherokee County:					
Cherokee	1,120	12–9	+6	−206	Water-bearing beds at 225, 375, 405, 475, and 585 feet; temp., 60°; water hard
Clarke County:					
Osceola	1,953			No flow.	
Clay County:					
Spencer	800	6	Many.		
Do	400				
Spencer (10 miles south)	600	4¼–3¼			Abandoned.
Clayton County:					
McGregor[10]	1,006	6–3	20	+ 62	Temp., 54°.
Do.[11]	520	6–3		+ 20	Temp., 52°.
Monona[11]	420				
Monona	417	6	70	212	
Do	452	6	None.		Abandoned.
Clinton County:					
Clinton[12]	1,035–1,497	10–5	1,736	+ 68	5 wells.
Do.[12]	1,065	5¼		+ 35	
Do.[12]	1,674	8–5	1,500	+ 45	
Do	1,159 1,175				2 wells.
Lyons	1,132				
Davis County:					
Bloomfield	1,817				
Delaware County:					
Manchester[13]	1,870	10–5		14	
Des Moines County:					
Burlington	2,430	6–5	70	38	
Do	507	5¼	45	Flows.	
Dickinson County:					
Lakepark	700	4	55	300	Temp., 50°.
Dubuque County:					
Dubuque[14]	802	4			Water at surface.
Do.[14]	955	6	340	+ 81	Several wells of about this depth.

[1] Record, Iowa Geol. Surv. Rept., vol. 6, 1896, p. 200.
[2] Ibid., p. 189.
[3] Ibid., p. 202.
[4] Record and analysis, ibid., pp. 326–328.
[5] Record, ibid., vol. 3, pp. 192–195.
[6] Record and analysis, ibid., vol. 6, 1896, pp. 266–267.
[7] Record, ibid., pp. 336–339.
[8] Ibid., pp. 261–262.
[9] Record and analysis, ibid., pp. 193–195.
[10] Ibid., pp. 185–188.
[11] Iowa Geol. Surv. Rept., vol. 6, 1896, p. 188.
[12] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 811; analysis, p. 827.
[13] Record and analysis, Iowa Geol. Surv. Rept., vol. 6, 1896, pp. 214–219.
[14] Ibid., pp. 208–214.

IOWA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Dubuque County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Dubuque	1,262	6	450		
Do.[1]	1,954	3	40	+ 1	
Do	1,300-1,400	13	2,000	Flow.	2 wells.
Do.[1]	1,765	3	40		
Do.[1]	1,000	5	580	+ 41	Several wells 965-1,060 feet.
Do	2,027				
Do	960 1,317				2 wells.
Do	1,927				
Do	1,416				
Do	1,100				
Franklin County:					
Hampton	1,708				
Fremont County:					
Randolph	1,768	8	Many.	No flow.	
Greene County:					
Jefferson	2,021	8-5		− 40	
Grundy County:					
Grundy Center	485			−150	
Hamilton County:					
Webster City[2]	1,250	8-6	70	+ 16	
Hancock County:					
Britt[3]	684	7		− 16	
Do	535	4½		−510	
Hardin County:					
Ackley[4]	920				
Harrison County:					
Dunlap[5]	1,535	6¼			
Henry County:					
Mount Pleasant[6]	1,125		165	− 30	
Howard County:					
Cresco	1,158				
Ida County:					
Holstein[7]	2,004	8-4		−275	
Iowa County:					
Amana[8]	1,640		100	+ 30	Temp., 60°.
Cono Township[9]	416			Flows.	
Homestead[10]	2,224	10-4		−117	
Jackson County:					
Sabula[11]	973		720	+ 78	
Jasper County:					
Newton[12]	1,400	5	Many.	− 90	
Jones County:					
Anamosa[13]	2,007	10-5	300	− 56	
Do	1,734				
Monticello[14]	1,198		175	− 40	
Keokuk County:					
Sigourney[15]	1,880	6-4½		30	
South English	420	4	None.		Abandoned.
Whatcheer	636				
Kossuth County:					
Algona[16]	1,050			− 69	
Lee County:					
Fort Madison[17]	689	6	600	− 20	
Do.[18]	720	6		+ 85	Temp., 55°.
Do.[18]	764	4		+ 20	
Keokuk[19]	710	6	250	+ 35	Temp., 64°; two other wells 700 feet deep.
Do.[19]	800	6		+ 47	Temp., 50°.
Do.[19]	2,000	12-10	3 wells 1,700	+ 30	Temp., 65°; 3 wells.
Do	900				
Do.[19]	2,230	10	300	+ 30	Another well 1,805 feet; water also at 600 and 900 feet.
Do	1,987	6-4			
Do	935		Many.	Flow.	
Montrose	850				
Mount Clara[20]	939			10	Formerly flowed 200 gallons.

[1] Record and analysis, Iowa Geol. Surv. Rept., vol. 6, 1896, pp. 208-214.
[2] Ibid., pp. 220-222.
[3] Analysis, ibid., p. 195.
[4] Record, ibid., vol. 3, pp. 189-192; vol. 6, pp. 219-220.
[5] Record and analysis, ibid., vol. 6, 1896, pp. 257-259.
[6] Ibid., pp. 320-321.
[7] Record, ibid., p. 222.
[8] *Record and analysis, ibid., pp. 286-287.*
[9] *Iowa Geol. Surv. Rept., vol. 9, 1898, p. 561.*
[10] Record and analysis, ibid., vol. 6, pp. 283-285.
[11] U. S. Geol. Surv., 17th Rept., 1895-96, part 2, p. 817.
[12] Record, Iowa Geol. Surv. Rept., vol. 6, p. 292.
[13] Ibid., pp. 262-265.
[14] Record and analysis, ibid., p. 265.
[15] Record, ibid., pp. 305-308.
[16] Ibid., p. 196.
[17] Record and analysis, ibid., pp. 321-322.
[18] Ibid., pp. 321-322.
[19] Ibid., pp. 323-326.
[20] Ibid., p. 322.

IOWA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Linn County:					
Cedar Rapids	1,450	5	150	+ 14	3 wells.
Do	1,300 to 2,100				Do.
Mahaska County:					
Oskaloosa [1]	2,800–3,000				Abandoned.
Do	2,517				
Marion County:					
Pella [2]	1,803	12–5	250	− 90	
Mills County:					
Glenwood [3]	2,000	10–4¼	83	−173	
Do.[3]	1,910		80	− 5	
Montgomery County:					
Redoak	560				Coal prospect.
Muscatine County:					
West Liberty [4]	1,768	6–4 3/16	½	Flows.	Temp., 65°.
Wilton Junction [5]	1,360	8–6	300	− 78	
O'Brien County:					
Sanborn	1,224	6	80	−459	
Osceola County:					
Sibley	763	4½	106	200	
Page County:					
Clarinda [6]	1,002			Flowed.	Coal prospect.
Shenandoah	700				
Palo Alto County:					
Emmetsburg [7]	874			− 34	
Do	810	6	12	− 26	
Plymouth County:					
Lemars [8]	1,560				
Pocahontas County:					
Pocahontas (3 miles south).	632				Unsuccessful.
Pocahontas (near)	1,300		Many.		
Bellville Township	1,300				Abundant supply.
Polk County:					
Des Moines [9]	3,000	10–3	400	+ 45	
Saylorville	1,800				
Pottawattamie County:					
Council Bluffs [10]	1,114				
Do. [10]	860				
Council Bluffs (school for deaf). [10]	1,091	4	56	+ 50	
Council Bluffs	840				
Poweshiek County:					
Grinnell [11]	2,003	10–4	105	−230	
Do	2,002				
Sac County:					
Odebolt	500				
Wall Lake	427				
Scott County:					
Davenport (bottling works). [12]	780		300	+ 59	
Davenport (Malt and Grain Co.). [12]	1,076	5	300	+ 13	Water from 1,050–1,076 feet.
Davenport (Gas Co.). [12]	1,200	5–4	400	+ 47	2 wells; water from near bottom.
Davenport (Glucose Co.). [13]	2,100–2,107	5		+ 77	4 wells.
Do. [14]	1,500	5	250	+ 54	
Davenport (city park) [15]	1,797	5	+125	22	Water at 1,175 feet.
Davenport (Kimball House). [16]	1,080	5	120	+ 20	Water at 1,075 feet.
Davenport (packing company). [14]	1,180	8–5	250	+ 45	
Davenport (Schmidt Building). [14]	1,200	4	73	+ 24	
Davenport (woolen mills). [14]	1,053	3¼	300	+ 35	Water from 700 and 1,050 feet.
Davenport (ice company). [14]	1,067	6–4	240	+ 10	Water from 775 and 1,064 feet.

[1] Record, Iowa Geol. Surv. Rept., vol. 6, pp. 308–310.
[2] Ibid., pp. 310–315.
[3] Record and analysis, ibid., pp. 340–347.
[4] Ibid., pp. 281–282.
[5] Ibid., pp. 280–281.
[6] Iowa Geol. Surv. Rept., vol. 6, pp. 339–340; record, ibid., vol. 12, pp. 28–32.
[7] Record, ibid., pp. 196–197.
[8] Ibid., pp. 232–235.
[9] Ibid., pp. 294–299.
[10] Analysis, Iowa Geol. Surv. Rept., vol. 6, p. 310.
[11] Record and analysis, ibid., pp. 287–292.
[12] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 812; Iowa Geol. Surv. Rept., vol. 6, p. 272.
[13] Record, ibid., p. 842; Iowa Geol. Surv. Rept., vol. 6, p. 272.
[14] Ibid., p. 811; Iowa Geol. Surv. Rept., vol. 6, p. 272.
[15] Am. Geol., vol. 3, 1889, p. 117; Iowa Geol. Surv. Rept., vol. 6, pp. 272–280; record, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, pp. 842–845.
[16] Record, U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, p. 844.

KANSAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Elk County:					
Howard	1,000		None.		Abandoned.
Do.[1]	1,226–1,410				
Ellis County:					
Hays (15 miles southwest).	1,177			+ 15	Artesian water at 500 salt water a short tance below and tervals to 933 feet.
Ellsworth County:					
Ellsworth	1,300				Salt, 730 to 880 feet; water at 1,300 feet.
Do	730	4½		−114	Salt water.
Kanopolis[2]	881	8–4			Salt water at 645 to 87
Wilson[3]	1,385	8–5			Salt water; abandon
Finney County:					
Eminence					
Garden City (one-half mile northwest).[4]	+1,000				
Garden City	902				
Garden City (8 miles south).	1,250				
Ravanna (north of)	+ 400		Many.	−200	Abandoned.
Ravanna	+ 400			− 45	Do.
Ford County:					
Dodge City (1½ miles east)	800				Unsuccessful.
Franklin County:					
Ottawa	1,002	8			Oil at 675 and 702 large volume of ga
Do	1,065				Salt water at 384 a feet; fresh water and 755 feet; ga water at 490 feet.
Geary County:					
Junction City (vicinity)	800				Sal water; abandon
Gove County:					
Goodwater	501	3	Few.		All in shale; aband
Catalpa (vicinity)	400				Good supply of fine no flow.
Jerome	400				
Jerome (near)	400				Good supply of fine at 400 feet; no flo
Graham County:					
Hill City (3 miles from)	400			No flow.	Shale to bottom.
Greeley County:					
Horace	1,370	10	30	− 830	Dakota sandstone re at 1,050 feet.
Tribune	500				Unsuccessful.
Greenwood County:					
Eureka[5]	503				Coal prospect; aban
Do	+1,000				In progress 1900; water 500 to 700 fe 800 to 900 feet.
Do	1,255				Brine at 499 feet.
Fall River	986	10–5½	1,000	− 77	Water at 416 feet water at 972 feet.
Do.[6]	1,480		Many.		
Madison	1,896½	6			For gas; unsuccessf
Neal	940	10–8½			For oil; water-beari at 822 feet.
Do	875				
Hamilton County:					
Coolidge	500	5½	90	Flows.	
Kendall	500				No water at that de
Do	537		70		Pumped; no flow.
Syracuse	1,000			− 90	
Harper County:					
Anthony[7]	2,335				
Harvey County:					
Halstead	+ 400				
Newton	1,045				Prospect borings.
Do	910–1,076				Do.
Haskell County:					
Santa Fe	1,200	6	Many.	− 200	Good water at 200 a feet.
Do	1,300	10–5½		− 100	
Hodgeman County:					
Jetmore	1,000				For coal.
Do	700 or 800			− 20–30	Not in use; abandon

[1] Record, Kan. Univ. Geol. Surv. Rept., vol. 3, pl. 29.
[2] Record, Mineral Resources of Kansas, 1898, pp. 94–95.
[3] Ibid., p. 97.
[4] Record, Kans. Univ. Geol. Surv. Rept., vol. 2, p. 27.
[5] Ibid., vol. 3, pl. 27.
[6] Ibid., vol. 1, pl. 13; vol. 3, pl. 25.
[7] Ibid., vol. 1, pl. 21; Mineral Resources o sas, 1898, p. 90.

KANSAS—Continued.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
ity[5]	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
.....	1,206 or 1,406(?)	6	None.	.....	
nty:					
lls.....	1,174	3	2	+ 40	Very saline water.
y:					
.....	432	.....	.....	.....	Salt water; abandoned.
(3¼ miles north-	400	.....	.....	.....	Salt water only.
.....	500	8	.....	— 50	Salt water.
nty:					
.....	600	.....	.....	.....	Water at 85 feet; salt water at 530 feet; weak flow of gas at 361½ feet.
nty:					
.....	+ 800	.....	.....	.....	Salt shafts.
n (1¼ miles	1,410	.....	.....	.....	Salt.
.....	1,000	.....	.....	.....	Salt well; 175 feet of salt.
ron Works.....	1,000	.....	.....	.....	Two salt shafts.
ity:					
alley[2].....	762	7½-6½	1¼	+ 6	Temp., 70°. Salt water and gas.
.....	985	6	.....	— 100	
.....	600	.....	.....	— 40	Small amount of gas at 548 feet; salt water at 606 feet.
nd vicinity.....	500-1,500	.....	.....	.....	Several wells for gas; not much found; salt water at 400 to 500 feet; no flow; abandoned.
.....	530	7	.....	— 16	
3 miles north)..	400	.....	.....	.....	Limited supply of water from thin sandstone in upper part of Benton.
County:					
orth[3].....	1,170	.....	.....	Flows.	Gas and water.
.....	2,116	.....	.....	.....	
xie.....	854	.....	.....	.....	City well.
on.....	729	5	.....	.....	Salt water.
.....	918	6¼	.....	.....	Salt water at 828 and 918 feet.
on (near)[4].....	757	6¼-5	.....	.....	Water at 132 and 656 feet; salt water at 348 and 757 feet, and trace of oil at 353 and 730 feet.
y:					
.....	408	.....	.....	.....	
7 miles south)..	500	.....	.....	.....	Unsuccessful; all in blue shale.
.....	725	.....	.....	.30	Unsuccessful; water at intervals to 200 feet, then shale to bottom.
.....	1,356	.....	.....	.....	Unsuccessful.
.....	2,005	6	.....	.....	Gas prospect; abandoned.
ounty:					
5 miles south-	500	.....	.....	.....	
e.....	400	6	Few.	.70	Salt water.
ty:					
.....	1,800	.....	.....	.....	For coal; unsuccessful.
County:					
le.....	609-617	.....	.....	.....	Gas wells.
.....	1,220	1¼	.....	.....	Salt water and gas found.
.....	1,397-1,500	.....	.....	.....	Oil wells; water at several horizons.
le.....	550	.....	.....	.....	Gas well.
lence.....	1,020	.....	.....	.....	Oil and gas.
.....	1,100	.....	.....	Flows.	
.....	1,041	8¼	.....	.....	Gas well.
.....	1,160	8¼-6¼	.....	.....	Gas well; water-bearing beds at 275, 640, and 895 feet.

ineral Resources of Kansas, 1898, p.

ans. Univ. Geol. Surv. Rept., vol. 1, pl. 21.

1, pl. 20; vol. 3, pl. 26.

[4] Ibid., vol. 1, pl. 16.

[5] Ibid., vol. 3, pl. 28.

[6] Ibid., vol. 1, pl. 11; vol. 3, pl. 22.

[7] Analysis, ibid., pp. 149-150.

KANSAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Morton County:					
Richfield[1]	670		22	Flows.	
Do	701		6	+125	Water is of unsatisf quality.
Do	600		6	Flows.	Temp., 66°; water feet.
Do	640		15	+ 25	2 wells; temp., 60°.
Marshall County:					
Marysville	1,360		Few.	Flows.	
Marysville (near)	1,100				
Meade County:					
Fowler					
Meade	800	6			Red Beds at 200 fee below.
Miami County:					
Paola[2]	1,075				City well.
Do	500-580	5¼-4¼	Many.	−0 to −400	Several gas wells.
Mitchell County:					
Asherville	638			− 26	Abundant supply o salty water.
Cawker City (2 miles northeast).	468			−217	Salt water.
Cawker City (10 miles north).	416			No flow.	Do.
Neosho County:					
Chanute[3]	741-982	4⅞			Several gas and oil
Do	806	6¼-5			Large flow of gas; water.
Do	752	5	5		Oil well; brine at 3 oil at 720, 724, a feet.
Erie	750		400		Mineral water.
Erie (2 miles north)	833		Many.	Flows.	Large flow of oil a and salt water.
Erie	813				Salt water at 400 f sand at 550 to 58
Galesburg	973				Salt water; abando
Rollin (near)	652		48		Oil well.
St. Paul	661-668			Flows.	Salty water; aban
Thayer	825				Oil wells.
Thayer (near)	1,064	6¼-4¼			Water at 376, 575, 8 1,064 feet.
Thayer	895	8¼-6¼			Water at 215 feet; 827-830 feet.
Ness County:					
Danby (6 miles southwest).	385			−110	
Ness City (14 miles north)	656	3	30	−356	
Ness City (8 miles south).	+400	6			
Ness City (10 and 12 miles southwest).	450, 437				Satisfactory supply water from D sandstone.
Ransom	653	6-3	Several.	60	Water in sandstone blue shale.
Osage County:					
Lyndon[4]	1,007				Salt water at 239 fe prospect; abandc
Osage Mission[5]	700				
Osborne County:					
Osborne	500				
Portis (6 miles northwest).	546			No flow.	Salt water.
Portis (8 miles northwest).	543	6		-200	Do.
Pawnee County:					
Larned	756		400		
Do	743	10-3	250	+ 50	Temp., 65°; salt wa
Phillips County:					
Cactus (6 miles south)	480			− 50	
Kirwin	514				
Long Island (4½ miles northeast).	650				Bored for oil or gas
Phillipsburg (a few miles northwest).	430				Small supply of wa
Pottawatomie County:					
Onaga	602	3-2	5		Gas and flowing w 533 to 559 feet.
St. Marys	1,128			Flows.	Salt water.

[1] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 157.
[2] Record, Kans. Univ. Geol. Surv. Rept., vol. 1, pl. 17.
[3] Ibid., p. 77, pl. 13; vol. 3, pl. 25.
[4] Record, Kans. Univ. Geol. Surv. Rept., pl. 27.
[5] Ibid., vol. 1, pl. 15.

KANSAS—Continued.

ion.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
County—Ctd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
.....	520	.....	.....	Flows.	Salt water.
.....	1,000	.....	.....	+ 6	Do.
.....	±800	.....	.....	− 15	Thick salt beds 600 to 800 feet; not used.
near).....	408	8	.....	No flow.	Bad water.
.....	1,000	.....	.....	.....	Salt.
.....	+800	.....	.....	.....	Several salt wells.
(south of)[1]..	1,307	.....	.....	.....	Salt.
ty:					
.....	1,110	.....	.....	− 16	Good water.
r[2].....	964	8	.....	.....	Much water to 400 feet, then 600 feet of salt and shale.
.....	1,230	.....	.....	.....	Salt prospect; abandoned.
nis Salt Co.)..	1,625	8–5	.....	− 30	Salt well.
shaft)[3].....	1,005	.....	.....	.....	
.....	916	10–2½	None.	.....	Do.
.....	980	10–2½	Few.	− 3	Do.
.....	400	.....	.....	.....	
miles south).	460	.....	.....	− 60	Much good water.
.....	1,403	.....	.....	Flows.	Salt water.
.....	444	3	20	−240	Water pure.
.....	558	8¼–6¼	20	.....	Water-bearing beds at 278 and 382 feet; water salty.
:					
.....	997	10–5	Many.	−300	Saline water.
ity:					
.....	1,605	14–4½	.....	120	Salt water at 500 feet.
.....	1,025	.....	.....	.....	
:					
.....	485	7	52	−130	Water at 130 feet.
miles south).	500	.....	.....	.....	No water supply.
ty:					
.....	900	.....	.....	.....	
.....	1,638	.....	.....	.....	Coal prospect; no coal; no flowing water.
(near).....	+ 400	.....	.....	.....	No water supply.
miles north-	546	.....	.....	.....	Salty water.
er.....	600	7	.....	−390	Salt water at 590 feet; abandoned.
ter (12 miles).	540	.....	Many.	−140	Salt water from sand 535 to 540 feet under 535 feet of shale.
r:					
.....	420	8	Many.	−180	
y:					
.....	800	6	.....	.....	Salt water only at 457 feet.
.....	438	6	Few.	−150	All in shale.
es north of ll River, near border of the	446	.....	.....	.....	
.....	700	.....	.....	.....	
(12 miles).	438	.....	50	.....	No flow.
unty:					
.....	2,000	.....	.....	.....	
.....	1,912	4–2½	.....	Flows.	Salt water and gas.
[8].....	2,006	4	.....	.....	
.....	1,000	.....	.....	.....	Not in use.
y:					
icinity)	800	4	None.	.....	Did not reach bottom of shale.
	448	7	.....	.....	
	400	7	None.	.....	
unty:					
a	1,100–1,200	.....	1	.....	
.....	1,350	6	None.	.....	Abandoned.
.....	2,200	6	None.	.....	Do.

[1] eral Resources of Kansas, 1898, p.

[5] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 158.

[6] Record, Kans. Univ. Geol. Surv. Rept., vol. 1, pl. 17.

[7] Ibid., vol. 3, pl. 27.

[8] Ibid., vol. 1, pl. 19; vol. 3, pl. 30.

KANSAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Wilson County:					
Benedict (southeast of)	2,414	13-6¼	.....	.....	Fresh water at 403 feet; strong salt water at from 1,096 to 2,414 feet.
Benedict (near)	827	8¼-5	11/16	.....	Oil well; fresh and salt water also found.
Do	1,050-1,147	4¾	.....	.....	For oil; salt water only.
Buffalo	1,170	.....	.....	.....	Only salt water.
Buffalo (2 miles west)	400-800	.....	.....	.....	Oil and water wells.
Fredonia[1]	1,224	.....	.....	.....	
Do	2,414	.....	None.	.....	Salt water at 354 and 1,195 feet; abandoned.
Neodesha[2]	1,101	8¼-5	.....	.....	Oil prospect; water at 230 and 820 feet; salt water at 420, 685, and 775 feet, and gas at 655 feet.
Do	±2,400	8¼	.....	.....	
Do	1,310	.....	.....	.....	
Do	2,414	6¼	Many.	.....	Sulphur water at 1,423 feet; salt water below.
Neodesha (near)	1,078	6¼-5	.....	.....	Oil and gas wells; water at 811 and 1,078 feet.
Woodson County:					
Neosho Falls	1,275	.....	.....	.....	Salt water at 361 feet.
Toronto[3]	1,452	.....	.....	Flows.	Salt water and some oil.
Do	940-782	.....	.....	.....	2 wells; some gas.
Do	1,140	.....	.....	.....	Oil at bottom of well.
Wyandotte County:					
Kansas City[4]	758	.....	.....	.....	
Do	2,360	.....	.....	.....	

[1] Record Kans. Univ. Geol. Surv. Rept., vol. 1, pl. 12; vol. 3, pl. 24.
[2] Ibid., pl. 11; vol. 3, pl. 22.
[3] Ibid., vol. 3, p. 119, pl. 29.
[4] Ibid., vol. 1, pl. 18; analysis, vol. 7, p. 255.

PUBLICATIONS RELATING TO DEEP BORINGS IN KANSAS.

Report of J. W. Gregory, field agent for the middle division: Fifty-first Congress, first session, Senate Ex. Doc. No. 222, pp. 145-172, Washington, 1890.

Water resources of a portion of the Great Plains, by Robert Hay: United States Geological Survey Sixteenth Annual Report, 1894-95, part 2, pp. 535-588, plates, Washington, 1895.

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The United States Geological Survey Bulletin No. 131, p. 115, Washington, 1895.

Mineral waters, by E. H. S. Bailey and others: University Geological Survey of Kansas, vol. 7, 1902.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton: United States Geological Survey Professional Paper No. 32, Washington, 1905.

KENTUCKY.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
y:	*Feet.*	*Inches.*	*Gals.*	*Feet.*	
.....	1,200	.....	.....	.....	
5 miles south-	1,370	.....	.....	.....	Several gas wells.
Junction (3 outheast).[2]	1,511	.....	.....	.....	Salt water at about 700 feet.
.....	650	.....	.....	.....	Oil well.
.....	± 400	.....	.....	.....	Gas well.
4 miles south).	1,715	13-10	.....	.....	For oil or gas; unsuccessful.
6 miles south).	2,100	13-10	.....	.....	Do.
Township	1,580	.....	.....	.....	
irg (1 mile	2,025	10-6¼	.....	.....	Gas well.
irg (1¼ miles	2,322	.....	.....	.....	For oil.
miles west)[5]...	+1,411	.....	.....	.....	Oil and gas.
.....	560	6	.....	.....	Unsuccessful.
.....	650	6	.....	.....	For oil; unsuccessful.
nty: le.....	600	.....	.....	.....	For oil or gas; in progress 1899.
nty: p unknown)...	850	.....	.....	.....	
County: rt[6].....	+ 896	.....	.....	.....	Several gas wells in vicinity; salt water at 400 feet; strong brine at 600 feet.
wn	500	.....	.....	.....	Oil, gas, and coal.
nty:	1,250	.....	.....	.....	
nty:	2,007	.....	.....	.....	Much water at 1,650 feet.
p unknown)...	1,480	.....	.....	.....	
nty: ille[9].....	1,600	.....	.....	.....	Some gas and oil at bottom.
ounty: le.....	1,700	.....	.....	.....	Small showing of oil and gas.
nding	+ 400	.....	.....	.....	Oil well.
ty: o[10].....	1,000	4	.....	.....	Brine at 765 feet; poor water below.
.....	1,480	.....	.....	.....	Salt water at 780 feet; none below.
.....	1,200	.....	.....	.....	
o (2 miles east)	1,000	.....	.....	.....	But little gas.
ty:	875	6	.....	.....	No water supply.
ity:	600	.....	.....	.....	For oil.
unknown.....	1,005-1,930	.....	.....	.....	5 wells.
nty	825	6	Many	Flows.	
y:	830	.....	.....	.....	
.....	+ 576	.....	.....	.....	
own	500	.....	.....	.....	No water below 30 feet.
ity Springs (6	1,000	6	Many.	Flows	Temp., 61½°.
near)[12].....	1,480	.....	.....	100	For oil or gas; unproductive; much salt water at 1,475 feet.

Surv., Petroleum, Gas, etc., by E.

id., p. 154.
155-156.
S. Geol. Surv. Folio No. 69, p. 3, 1900
2d Geol. Surv. Rept., Vol. I[5], pp.

Surv., Petroleum, Gas, etc., by E.
-193.

[7] Record, Ky. Geol. Surv., Description of Jackson Purchase Region, pp. 321-326.

[8] Record and analysis, Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 298-300.

[9] Ky. Geol. Surv., Petroleum, Gas, etc., by E. Orton, pp. 162-165.

[10] Ibid., p. 194.

[11] Ky. Geol. Surv. Rept., vol. 1, new ser., p. 92.

[12] Record, Pa. Geol. Surv. Rept., Vol. I[5], p. 340.

KANSAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Wilson County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Benedict (southeast of)	2,414	13–6¼			Fresh water at 403 feet; strong salt water at from 1,096 to 2,414 feet.
Benedict (near)	827	8¼–5	1½		Oil well; fresh and salt water also found.
Do	1,050–1,147	4¼			For oil; salt water only.
Buffalo	1,170				Only salt water.
Buffalo (2 miles west)	400–800				Oil and water wells.
Fredonia[1]	1,224				
Do	2,414		None.		Salt water at 354 and 1,195 feet; abandoned.
Neodesha[2]	1,101	8¼–5			Oil prospect; water at 230 and 820 feet; salt water at 420, 685, and 775 feet, and gas at 655 feet.
Do	±2,400	8¼			
Do	1,310				
Do	2,414	6¼	Many.		Sulphur water at 1,423 feet; salt water below.
Neodesha (near)	1,078	6¼–5			Oil and gas wells; water at 811 and 1,078 feet.
Woodson County:					
Neosho Falls	1,275				Salt water at 361 feet.
Toronto[3]	1,452			Flows.	Salt water and some oil.
Do	940–782				2 wells; some gas.
Do	1,140				Oil at bottom of well.
Wyandotte County:					
Kansas City[4]	758				
Do	2,360				

[1] Record Kans. Univ. Geol. Surv. Rept., vol. 1, pl. 12; vol. 3, pl. 24.
[2] Ibid., pl. 11; vol. 3, pl. 22.
[3] Ibid., vol. 3, p. 149, pl. 29.
[4] Ibid., vol. 1, pl. 18; analysis, vol. 7, p. 255.

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Water resources of a portion of the Great Plains, by Robert Hay: United States Geological Survey Sixteenth Annual Report, 1894–95, part 2, pp. 535–588, plates, Washington, 1895.

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Report of the Board of Irrigation, Survey, and Experiment for 1895 and 1896 to the Legislature of Kansas, 238 pages, plates, Topeka, 1897.

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Mineral waters, by E. H. S. Bailey and others: University Geological Survey of Kansas, vol. 7, 1902.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton: United States Geological Survey Professional Paper No. 32, Washington, 1905.

KENTUCKY.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gals.*	*Feet.*	
Barren County:					
Glasgow[1]	1,200				
Glasgow (5 miles southwest).[2]	1,370				Several gas wells.
Glasgow Junction (3 miles southeast).[3]	1,511				Salt water at about 700 feet.
Bell County:					
Pineville	650				Oil well.
Boone County:					
Walton	+ 400				Gas well.
Boyd County:					
Ashland (4 miles south).	1,715	13–10			For oil or gas; unsuccessful.
Ashland (6 miles south).	2,100	13–10			Do.
Ashland Township	1,580				
Catlettsburg (1 mile west).[4]	2,025	10–6¼			Gas well.
Catlettsburg (1¼ miles south).	2,322				For oil.
Boyle County:					
Atoka (14 miles west)[5]	+1,414				Oil and gas.
Danville	560	6			Unsuccessful.
Perryville	650	6			For oil; unsuccessful.
Bracken County:					
Brooksville	600				For oil or gas; in progress 1899.
Breathitt County:					
(Township unknown)	850				
Breckinridge County:					
Cloversport[6]	+ 896				Several gas wells in vicinity; salt water at 400 feet; strong brine at 600 feet.
Butler County:					
Morgantown	500				Oil, gas, and coal.
Calloway County:					
Paducah[7]	1,250				
Campbell County:					
Newport[8]	2,007				Much water at 1,650 feet.
Carter County:					
(Township unknown)	1,480				
Christian County:					
Hopkinsville[9]	1,600				Some gas and oil at bottom.
Cumberland County:					
Burkesville	1,700				Small showing of oil and gas.
Cloyds Landing	± 400				Oil well.
Daviess County:					
Owensboro[10]	1,000	4			Brine at 765 feet; poor water below.
Do	1,480				Salt water at 780 feet; none below.
Do	1,200				
Owensboro (2 miles east)	1,000				But little gas.
Fayette County:					
Lexington	875	6			No water supply.
Fleming County:					
Elizaville	600				For oil.
Floyd County:					
Township unknown	1,005–1,930				5 wells.
Franklin County:					
Frankfort	825	6	Many	Flows.	
Fulton County:					
Hickman	830				
Do	+ 576				
Grant County.					
Williamstown	500				No water below 30 feet.
Grayson County					
Grayson Springs (6 miles).[11]	1,000	6	Many.	Flows.	Temp., 61½°.
Pactolus (near)[12]	1,480			100	For oil or gas; unproductive; much salt water at 1,175 feet.

[1] Ky. Geol. Surv., Petroleum, Gas, etc., by E. Orton, p. 154.
[2] Record, ibid., p. 154.
[3] Ibid., pp. 155–156.
[4] Record, U. S. Geol. Surv. Folio No. 69, p. 3, 1900
[5] Record, Pa. 2d Geol. Surv. Rept., Vol. I⁵, pp. 340–341.
[6] Ky. Geol. Surv., Petroleum, Gas, etc., by E. Orton, pp. 191–193.
[7] Record, Ky. Geol. Surv., Description of Jackson Purchase Region, pp. 321–326.
[8] Record and analysis, Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 298–300.
[9] Ky. Geol. Surv., Petroleum, Gas, etc., by E. Orton, pp. 162–165.
[10] Ibid., p. 194.
[11] Ky. Geol. Surv. Rept., vol. 1, new ser., p. 92.
[12] Record, Pa. Geol. Surv. Rept., Vol. I⁵, p. 340.

KENTUCKY—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Greenup County:					
Greenup (1¼ miles east)	940				Some oil at 400 feet; salt water at 500 feet; abandoned.
Greenup (1 mile)	+1,300				Some oil at 580 feet; abandoned.
Hancock County:					
Hawesville [1]	±1,500				Salt water only.
Hardin County:					
Westpoint (vicinity) [2]	400				For gas; unsuccessful.
Harlan County:					
Cloverfork	423	2			
Harrison County:					
Cynthiana	1,000-1,300			− 8	Several wells.
Henderson County:					
Henderson [3]	+ 459				Coal prospect.
Do. [4]	+ 900			Flows.	Brine.
Henderson (near)	1,024				Do.
Henderson (16 miles south). [5]	430 or 536				2 wells; one yields gas.
Jefferson County:					
Louisville (Dupont's) [6]	2,086	3	264	+170	Mineral water; temp., 86.1° (or 76¼°?).
Louisville (Phœnix Brewery).	1,800	8	Many.	+ 60	
Louisville (St. Patrick's). [7]	1,900		Many.	Flows.	Temp., 57.2°; salt water.
Louisville (Haynes's farm). [8]	1,000				Some gas at 400 feet.
Louisville (McGehee farm). [8]	1,000				No product.
Jessamine County:					
Harrodsburg (near)	485	5			Water unfit for use.
Keene	2,000				For oil 40 years ago.
Johnson County:					
Township unknown	1,318-1,750				2 wells.
Kenton County:					
Covington	1,360				
Lawrence County:					
Blaine Creek mouth [9]	2,597				For oil or gas; unproductive.
Blaine Creek mouth (1¼ miles from). [10]	1,840				Do.
Griffith Creek	2,407				
Hood Creek [11]	1,625				Oil well.
Laurel [12]	1,625				Sulphur water at 1,60[illegible] feet.
—— [13]	1,840-2,597				For oil or gas; unsuccessful.
Louisa (20 miles west) [14]	2,105				For oil or gas; unproductive.
Louisa (9 miles southwest). [15]	2,407				Do.
Township unknown					
Lee County:					
Township unknown	815				
Letcher County:					
Whitesburg	400				Salt wells.
Livingston County:					
Smithland [16]	1,200				Unsuccessful.
Smithland (Taylor farm)	+1,500				
Lyon County:					
Eddyville (below)	1,315				Water 200 to 300 feet.
Grand Rivers (near)	1,315				Oil prospect; abandoned.
Madison County:					
Panola	1,700	4			Salt water at 150 and 1,700 feet.
Magoffin County:					
Hendricks	2,484	8-5			Some oil; no water below 825 feet.

[1] Ky. Geol. Surv., Petroleum, Gas, etc., by E. Orton, p. 194.
[2] Record, Pa. Geol. Surv. Rept., Vol. I⁵, pp. 180-181.
[3] Record, Ky. Geol. Surv. Rept., 1854-55, pp. 32-36; Petroleum, Gas, etc., pp. 195-196.
[4] Ky. Geol. Surv., Petroleum, Gas, etc., p. 195.
[5] Ibid., p. 196.
[6] Record and analysis, Am. Jour. Sci., 2d ser., vol. 27, pp. 174-178.
[7] Ky. Geol. Surv., Petroleum, Gas, etc., pp. 169-170.
[8] Ibid., p. 173.
[9] Record, Pa. 2d Geol. Surv. Rept., Vol. I⁵, pp. 335-336.
[10] Ibid., pp. 336-337, U. S. Geol. Surv. Folio No. 105.
[11] Ibid., p. 339.
[12] Record, Pa. 2d Geol. Surv. Rept., Vol. I⁵, p. 339.
[13] Ibid., pp. 335-339.
[14] Ibid., p. 338.
[15] Ibid., pp. 337-338.
[16] Ky. Geol. Surv., Petroleum, Gas, etc., p. 198.

KENTUCKY—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Marion County:					
Warfield (township)	1,307				
Martin County:					
Inez	2,200				
Do	950				For oil.
Warfield (near)[1]	+1,307				Gas well.
Township unknown	1,119				
Warfield (township)	1,790–1,826				2 wells.
Meade County:					
Boones Landing[2]	500–579				Several gas wells.
Brandenburg[3]	400–765				Gas wells; some brine.
Mercer County:					
Harrodsburg	1,560	8		Flows.	Water at 1,100 feet; no gas.
Ohio County:					
Beaver Dam (1¼ miles southeast).	900				No oil or water; abandoned.
Hartford	1,000				Salt water.
Hartford (1¼ miles northeast).	+1,300			Flows.	Gas and salt water.
Oldham County:					
Lagrange[4]	1,500				Flow of salt water at 1,400 feet; no gas.
Do.[4]	1,200				Salt water at 1,200 feet; no gas.
Lagrange (1 mile south)[4]	565				Gas well.
Perry County:					
Hazzard (near)[5]	+ 400				Salt well.
Leatherwood Creek (mouth).[6]	410				Salt wells.
Pike County:					
Township unknown	1,590				
Powell County:					
Township unknown	1,303				
Pulaski County:					
Greenwood (2 miles southeast).	1,600				For oil, none found; abandoned.
Do	1,100				Abandoned.
Union County:					
Morganfield[7]	525	2			For oil; abandoned.
Uniontown	1,079	4		Flows.	For gas.
Uniontown (Davis mill).	+ 400	5–6		Flows.	Salt water.
Warren County:					
Bowling Green[8]	1,782				But little oil, gas, or water.
Bowling Green (vicinity).[9]	600–1,200				Several prospects for oil or gas; some gas.
Bowling Green (15 miles northwest).	600–700				Several wells yielding heavy oil.
Bowling Green	1,300				Oil well.
Do	600				Do.
Wayne County:					
Monticello	200–700				Oil wells.
Whitley County:					
Brummetts Station	1,000	6		– 5	Some gas at 300 feet.
Cumberland Falls (vicinity).	+ 400				Salt.
Halsey (near)	500	2			Coal prospect; some water at 60 feet.
Williamsburg (10 miles above).	500	6			For oil; unsuccessful.
Township unknown	1,900				
Do	1,003 1,715 2,032 2,141				4 wells.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 339-340.
[2] Ky. Geol. Surv., Petroleum, Gas, etc., pp. 176-177.
[3] Ibid., pp. 171-172, 176.
[4] Ibid., pp. 167-168.
[5] Record, Ky. Geol. Surv. Rept., 1854-55, pp. 36-39.
[6] Ky. Geol. Surv. Rept., 1854-55, p. 228.
[7] Ky. Geol. Surv., Petroleum, Gas, etc., p. 205.
[8] Ibid., pp. 159-160.
[9] Ibid., pp. 160-162.

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Seventh report on oil and gas fields of western Pennsylvania for 1887–88, by John F. Carll: Pennsylvania Second Geological Survey Reports, Volume I[5], 356 pages. Harrisburg, 1890.

Kentucky Geological Survey Report for 1854–55, by D. D. Owen, Frankfort, 1856.

Occurrence of petroleum, natural gas, and asphalt in western Kentucky, by Edward Orton: Kentucky Geological Survey Report, 1888–89, 232 pages, Frankfort.

LOUISIANA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Acadia Parish:					
Crowley	635	4	312	− 6	Pumps 347 gallons; temp., 62°; supply from 120 to 180 feet.
Evangeline[1]	1,500–2,600				Many oil wells.
Avoyelles Parish:					
Marksville	+1,282	16–4			Oil well in progress.
Bienville Parish:					
Arcadia (Railroad well)	540	8–6	50	−130	Water at 40, 165, and 520 feet; hard.
Arcadia (compress)	535	5–3½		− 36	
Bossier Parish:					
Bossier	600	4		− 30	Water at 225 feet; blue clay, no water 250 to 600 feet.
Collinsburg (6 miles southwest of, at Lake Point).	600	2½		− 15	Water 232 to 242 feet; blue clay, no water 242 to 600 feet.
Caddo Parish:					
Dixie (3 miles southwest of).	425				Hard, salty water; abandoned.
Furrh	750	3			No water.
Shreveport (ice factory)[2]	996	4	30	+ 15	Brine with gas; temp., 83°; fresh water at 200 feet which pumps 25 gallon
Shreveport (Texas and Pacific Junction).	561	7		− 50	Water at 280 feet; no water below.
Uni	650				No water.
Calcasieu Parish:					
Calcasieu	2,200		250	No flow.	Oil well; salty water.
Edgerly	535	10	225		Pumps 1,800 gallons per minute; water very warm.
Fenton (8 miles southeast).[3]	2,100				Oil well; abandoned.
Lake Charles	535	6–4	104	+ 18	Four wells; temp., 64°.
Do[4]	500	6	210	Flows.	
Do	510	6–4		Flows.	Two wells.
Lake Charles (Hoo-Hoo Park).	2,400				For oil; unsuccessful.
Lake Charles (2 miles east).	498	4	100	+ 10	
Lake Charles (2 miles southeast).[5]	2,406				Do.
Money Hill	2,200		250	Flows.	Artesian salt water, 1,000 to 1,005 feet; hot artesian salt water, 2,200 feet.
Oberlin (6 miles southeast, at Spring Hill).[6]	+1,500				For oil; unproductive.
Sulphur[7]	450				Sulphur test well.
Do[7]	1,230				Sulphur test well; strong flow of artesian water.
Do[8]	602				
Sulphur (6 miles southwest).[9]	800				Oil well in progress.
Sulphur (3 miles west)[9]	450				For oil; abandoned in large gravel.
Vinton[10]	1,000			Flows.	Artesian sulphur water, 400 to 500 feet.
Do[11]	540		33	Flows.	
Vinton (4 miles north)[12]	500				Oil well abandoned in large gravel.
Welsh[12]	1,500				Abandoned oil well; many oil wells in this vicinity.
Caldwell Parish:					
Columbia	503	4–2	20	+ 35	
Cameron Parish:					
Hackberry	1,457				For oil; unproductive.
Catahoula Parish:					
Leland	1,850	6		+ 6	Salt water with gas, temp., 86.4°.

[1] La. Geol. Surv. Rept., 1902, p. 268, U. S. Geol. Surv. Bull. 212, pp. 127–130.
[2] Record, La. Geol. Surv. Rept., 1899, p. 200.
[3] U. S. Geol. Surv. Bull. 212, p. 137.
[4] La. Geol. Surv., 1902, p. 240.
[5] Record, ibid., p. 271.
[6] La. Geol. Surv., 1902, p. 270.
[7] Record, ibid., 1899, p. 25.
[8] Ibid., 1902, p. 272.
[9] U. S. Geol. Surv. Bull. 212, p. 137.
[10] Ibid., p. 135.
[11] La. Geol. Surv., 1902, p. 241.
[12] U. S. Geol. Surv. Bull. 212, p. 136.

LOUISIANA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Claiborne Parish:					
Haynesville	600	4-3	1	− 20	Soft water.
Concordia Parish:					
Ferriday	950			Flows.	Brine.
De Soto Parish:					
Frierson (2¼ miles northeast).	1,500	8-4	10	Flows.	Salt water with gas at 998; temp., 70°.
East Baton Rouge Parish:					
Baker[1]	850	2		+ 16	
Baton Rouge[2]	758	8-4¼	350	− 6	
Do	760	10-6		Flows.	Pumps 350 gallons.
Grant Parish:					
Colfax[3]	1,128	2¼	40	+ 65	Temp., 62°; salt water; much gas.
Pollock	910	8-4	2	Flow.	Artesian water at 225 feet; no water below.
Rochelle	565		1	Flows.	Salt water with some gas; pumps 75 gallons.
Iberia Parish:					
Avery Island (Petite Anse.)[4]	1,005				Rock salt below 166 feet.
Delcambre (Jeffersons Island.)[5]	2,090				Rock salt below 344 feet.
Do	442				
Jeanerette[6]	700			5	
Weeks (Grande Cote)[7]	500				Rock salt below 140 feet.
Jackson Parish:					
Jonesboro	545	5	40	− 34	
Do	538	4		− 34	
Jonesboro (1 mile south, at Plymouth).	521				Water at 360 to 380, 418 to 430, 492 to 520 feet.
Lincoln Parish:					
Ruston (waterworks)	425	8-6	68	110	Water from 100 to 126 and 373 to 425 feet.
Ruston (compress)	449	4	68	−140	
Madison Parish:					
Delta	1,200			− 38	No water below 135 feet.
Natchitoches Parish:					
Goldonna	475				Test well.
Luella	707	4		Flows.	Artesian salt water at 640 and 700 feet.
Marthaville (3 miles west, at Boleyn).	412	1		+ 20	Bored deeper and lost flow.
Montrose	496	6			Abandoned; no water.
Natchitoches (Normal School).[8]	726	6-2¼		Flows.	Salt water; pumps 25 gallons.
Do	457	4		− 4	Salt water.
Orleans Parish:					
New Orleans[9]	600-700			Flows.	Many wells; water brackish.
Do	1,000-1,200			+ 15	Several wells; temp., 68°.
Do.[9]	1,356		40	Flows.	Salty; gas escapes 830 cubic feet in 24 hours.
New Orleans (2 miles north, at Lake City).[10]	900			+ 60	Temp., 78°.
Ouachita Parish:					
Cheniere (3 miles southeast).	515			Flows.	Artesian water 265 to 275, 355 to 430, 465 to 515 feet.
Monroe (ice factory)	485	5-3¼	50	+ 40	Soft water.
Do	400	7-3¼	20	Flows.	Do.
Monroe (light and power house).	500			Flows.	
Monroe	+ 400	7-3¼		+ 40	Many artesian wells.
Do	+ 400	4	30	Flows.	Soft water.
Monroe (one-half to 1¼ miles north).	+ 400			Flow.	3 wells.
Rapides Parish:					
Alexandria (waterworks).	560	4-2¼	70	+ 12	Pumping capacity 250 gallons.
Do	760	10-4			Do.
Alexandria (city square)	473	1¼	+ 10	− 60	Flowed until city waterworks installed.
Alexandria	606	2		− 49	Do.
Alexandria (ice factory)	580	8		60	Abandoned.
Alexandria	621	8			Do.
Alexandria (ice factory)	924		125	Flows.	Soft water.
Alexandria (railroad well).	858	6-4			Water at 850 feet; abandoned.

[1] La. Geol. Surv. Rept., 1902, p. 230.
[2] Ibid., p. 229.
[3] Record, ibid, p. 211.
[4] Ibid., Rept. 1899, p. 244.
[5] Ibid, p. 255.
[6] Ibid., 1902, p. 232.
[7] Ibid., 1899, pl. 27.
[8] Record, La. Geol. Surv. Rept., 1902, p. 210.
[9] Ibid., pp. 221-222.
[10] Ibid., p. 222.

LOUISIANA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Rapides Parish—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Boyce (railroad well)	810	6–4		+ 18	Well caved and abandoned; artesian fresh water at 300 and 625 feet artesian salt water at 808 feet; temp., 69°.
Pineville (State insane asylum).	1,020				
Pineville	720	6			Oil well; abandoned.
Do	428				
Sabine Parish:					
Loring	704	6	30	−100	Water at 188 to 190, 220 to 230, 251 to 264, 436 to 444, 460 to 462, 505 to 507, 524 to 528, 536 to 540, 545 to 549, 560 to 566, 670 to 704 feet.
Loring (1 mile west, at Plymouth).	566	4	20	−100	Salty and alkaline.
Negreet[1]	630	8	30	+ 18	Artesian water at 212 and 350 feet.
Noble	400				Water from 160 feet.
Plymouth	521	4	25	−100	Salty.
St. Landry Parish:					
Melville (10 miles south)	2,103			Flows.	Soft artesian water at [illegible] to 555 feet; strong artesian sulphur water at 2,003 feet.
St. Martin Parish:					
Breaux Bridge (Anse la Butte).[2]	523				Abandoned oil well; artesian water at 356 to [illegible] feet.
Do.[3]	+1,261				Oil well; in progress; [illegible] water at 1,261 feet.
St. Mary Parish:					
Belle Isle[4]	400				Rock salt below 270 feet.
Do	400				Quicksand.
Do	465				Rock salt below 240 feet.
Do	660				Rock salt below 370 feet.
Do	748				Rock salt below 248 feet.
Crawford	692	4	18	+ 2	Pumps 347 gallons; temp. 62°.
Crawford (2 miles south, at Cote Blanche).	450		104	−32	
Glencoe[5]	625				
Do	612			Flows.	
St. Tammany Parish:					
Abita Springs[6]	585	1¼	25	+15	
Covington[7]	572		21	+ 2	
Covington (1 mile east, at Claiborne).	630	2	30	Flows.	Temp., 73°.
Covington (2 miles north).[8]	610	2¼	60	Flows.	Do.
Covington (10 miles northwest, at Singletry's still).[8]	560	2		+18	
Mandeville Junction[9]	598			Flows.	
Tangipahoa Parish:					
Hammond[10]	570				Artesian water at 300 feet.
Do	473	5	300	+12	
Vernon Parish:					
Pickering	740	8–6			No water.
Webster Parish:					
Yellow Pine	1,015	4–3			Do.
West Feliciana Parish.					
Bayou Sara	736	4	347	+ 2	Temp., 63°.
Do	450			+ 1	
Winn Parish:					
Coldwater (Drake's Salt Works).	1,011	10	20	+35	Salt water; temp., 75°.
Dodson (1 mile south, at Pyburn).	600	6 4		+ 18	2 wells; company refuses information.
Dodson (2 miles south, at Winona).	454	4		−90	Abandoned; too much quicksand.
Winnfield	700			Flows.	Soft water; shells common from 20 to 490 feet.
Winona	454	4		90	Too much quicksand, well abandoned.

[1] Record, U. S. Geol. Surv. Bull. 212, p. 55.
[2] Ibid., pp. 130–131.
[3] Ibid., p. 63.
[4] Record, La. Geol. Surv. Rept., 1899, p. 224.
[5] Ibid., p. 258.
[6] La. Geol. Surv. Rept., 1902, p. 226.
[7] Ibid., p. 224.
[8] Ibid., p. 227.
[9] Ibid., p. 223.
[10] Record, ibid., p. 228.

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Geology and water resources of northern Louisiana and southern Arkansas, by A. C. Veatch: Prof. Paper U. S. Geol. Survey No. 46. (In preparation.)

MAINE.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Cumberland County:					
Portland	505	6	13	−100	Rock at 100 feet.
Kennebec County:					
Augusta	570	.....	10	No flow.	In granite.
Hancock County:					
Castine	675	8	.....	−27	

MARYLAND.

Allegany County:					
Cumberland	2,000	8	None.	.....	Abandoned.
Frostburg	700	1¼	None.	.....	Do.
Anne Arundel County:					
Bay Ridge	470	6–4	20	.....	Irony water.
Baltimore City:					
National Brewery	450	6	200	No flow.	
Maltby property	900	.....	Many.	No flow.	
Spring Garden Brewery	500	.....	.....	No flow.	
Hannis Distillery	800	.....	.....	No flow.	
Bauernschmidt's Brewery.	400	.....	25	.....	
Von Der Horst's Brewery.	435	8	25	No flow.	
Brehm's Brewery	1,300	.....	120	No flow.	
Adler's Brewery	800	.....	.....	.....	
Baltimore County:					
Arbutus	775	.....	.....	.....	Not finished; in gneiss.
Seawall	562	.....	None.	.....	
Sparrows Point	495	.....	.....	.....	No water below 210 feet.
Cecil County:					
Elkton	490	2¼	.....	.....	Water very unsatisfactory; temp., 45°.
Do	400	.....	.....	.....	Abandoned.
Do	407	.....	.....	.....	Unsuccessful.
Charles County:					
Indian Head	463	6	11	No flow.	
Frederick County:					
Frederick	1,140–996	.....	70	+3	
Garrett County:					
Deer Park	2,010	5	.....	Flows.	
Queen Anne County:					
Centerville [1]	665	.....	Many.	Near surface.	Water at 428 and 665 feet.
Somerset County:					
Crisfield	1,018	3	Pumps 200.	Flows.	Flows 40 gallons; saline water.
Do	1,033	4	130	Flows.	Saline water.
Do.[2]	1,090	6	.....	Flows.	Do.
Talbot County:					
Claiborne [3]	440	6	Many.	.....	Water also at 380 feet.
Easton	600	3	None.	.....	No water below 100 feet.

[1] Record, N. J. Geol. Surv. Rept., 1899, pp. 81–83.
[2] Record, U. S. Geol. Surv. Bull. 138, pp. 128–130.
[3] U. S. Geol. Surv. Bull. 138, p. 132.

MARYLAND—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Talbot County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Tilghmans Island	370–420		Many.		4 wells.
Tunis Mills	430	2	Pumps 100.	Flows.	Flows 6 gallons.
Wicomico County:					
Salisbury [1]	424				Water at 267 feet.
Worcester County:					
Pocomoke City [2]	496	6	50	Flows.	Pumps 100 gallons p minute.

[1] Record, N. J. Geol. Surv. Rept., 1899, pp. 113–115. [2] Ibid., pp. 116–117.

PUBLICATIONS RELATING TO DEEP BORINGS IN MARYLAND.

United States Geological Survey Bulletin No. 138, pp. 128–132.
New Jersey Geological Survey Reports for 1898 and 1899.

MASSACHUSETTS.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Berkshire County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Dalton	+400		Many.	No flow.	
North Adams	500	8	625	—4	Very hard water.
Stockbridge	650	8			Unsuccessful.
Bristol County:					
Fall River (?)	407	8	75		
New Bedford	510	6	2¼	No flow.	
New Bedford (Clarks Cove Guano Co.).	504				
Taunton	975	8	52	—12	Water too irony.
Franklin County:					
Turners Falls	900	6		No flow.	Water too hard.
Hampden County:					
Holyoke	400	8	400	20	
Do	800	8	600	20	
Do	720	8	400	-14	
Do	1,005	8	Many.	No flow.	Water too irony.
Hampshire County:					
Northampton	3,710	8	7	No flow.	Unsuccessful.
Do	4,022				Do.
West Cummington	625	8	2¼	No flow.	Water too irony.
Middlesex County:					
Malden	650	8	65	No flow.	Water of fair quality.
Waltham	460		Very few	No flow.	
Watertown	700		Many.		
Norfolk County:					
Franklin	450	6	27	-10	
Readville	500	8	1,500	-15	
Walpole	1,000		15		
Suffolk County:					
Boston	610				
Boston (Eastern Cold Storage).	400	8	70	No flow.	
Boston (corner Huntington avenue and Gainesboro street).	512	8	Few.	No flow.	Bad water.
Boston (corner Commercial and Prince streets).	1,750			No flow.	
Boston (No. 34 Providence street).	2,503	7⅝		5	Sulphur water; good w 459–484 feet; well al doned.
Boston (Park square)	2,567				No water below 500 fe
Cambridge (Dow Soap Works).	500				Unsuccessful.
Cambridge (Morse and White streets).	462	6			Do.
Cambridge	400				Do.
Dorchester	870–900			No flow.	2 wells; water very sa
Roxbury	502	6		20	
Do	403				
Worcester County:					
Princeton	900		Few.		

MICHIGAN.

ion.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
is	1,215		None.		Abandoned.
:					
	1,275–1,400				Several borings for oil; not much found.
	650	5	200	+20	Temp., 52°; several wells.
	1,026–1,269				Several salt wells.
Bay River).[8]	1,025				Salt well; flow of mineral water at 400 feet.
	1,850				For oil; unsuccessful.
	774–980				Salt wells.
	715–1,200				Numerous salt wells in vicinity.
	505				Salt wells in upper salt beds.
	1,600				
	1,003–1,007				2 wells.
	2,865				Brine at 2,141–2,306 feet.
ear)[6]	495	8			
	755				
	800				
[9]	810–1,133				2 salt wells.
(3 miles	465				
	1,000				
	664				Salt well.
	1,000–1,013				Several salt wells.
City[12]	3,508				
	1,020				Drill hole for copper ore.
	1,800				
	2,200		160	Flows.	Temp., 58°; mineral water.
:					
bor[15]	1,205				
	1,400	10–6	Many.	−30	
	750	8		−30	Abundant yield of strong mineral water.
ings[16]	874				
	1,438	10–5	15	+15	Temp., 60°.
	1,140				
Benton Harbor[18]	700–1,600				
	600				Strong brine at 870 feet.
:					
west of)[20]	447				Water at 223 feet; brine at 282 feet.
	1,200				
	2,200				
y:					
					Several wells.
[22]	440			−16	Water at 116 feet only.
	460				
	440			Flows.	
	1,500				Unsuccessful.
	2,200				Water at 87 feet; brine at 387 feet.
	1,760				
	2,300				Water at 90 feet; brine at 780 feet.
nty:					
[25]	400–482	8		Flow.	Temp., 46°.

h. Geol. Surv. Rept., 1881–1893, vol. -45, pl. 4.
-47, pl. 5.
Surv. Rept., 1873–1876, vol. 3, part

d., p. 182.
., 1881–1893, vol. 5, part 2, p. 50,

903, vol. 8, part 2, p. 170.
893, vol. 5, part 2, p. 58.
tate Board of Geol. Surv. of Mich.,

h. Geol. Surv. Rept., 1881–1893, vol.
1873–1876, vol. 3, part 1, p. 96.
903, vol. 8, part 2, p. 169.
id, 1873–1876, vol. 3, part 1, p. 182.
. Rept. State Board of Geol. Surv.
pp. 224–226.
h. Geol. Surv. Rept., 1881–1893, vol.
pl. 18.

[14] Analysis, ibid., p. 59.
[15] Record, ibid., p. 51, pl. 7.
[16] Ann. Rept. State Board of Geol. Surv. of Mich., 1901, p. 213.
[17] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 73, pl. 44
[18] Ann. Rept. State Board of Geol. Surv. of Mich., 1901, pp. 213–214.
[19] Record, Mich. Geol. Surv. Rept., 1873–1876, vol. 3, part 1, p. 93.
[20] Ibid., pp. 87–88.
[21] Ibid., 1881–1893, vol. 5, part 2, p. 51, pl. 10.
[22] Ibid., p. 50.
[23] Ibid., p. 67.
[24] Ibid., p. 55, pl. 16.
[25] U. S. Geol. Surv. Water-Sup. and Irr. Paper No. 30, p. 87.

MICHIGAN—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Cheboygan County:					
Cheboygan[1]	700				
Do	452	10-8		To surface.	
Do.[2]	2,750				
Indian River	414	2		−12	
Chippewa County:					
Neebish Island[3]	565				
Clinton County:					
St. Johns	1,200				Unsuccessful.
Do.[4]	608				Waterworks well.
Crawford County:					
Grayling					Many wells.
Do	2,560	6			
Do.[5]	2,750				
Delta County:					
Escanaba[6]	640				
Eaton County:					
Charlotte[7]	2,209	6		20	
Do	730				
Emmet County:					
Petoskey	575	10-8	450	−18	Temp., 50°.
Genesee County:					
Flint[8]	1,200				Salt well; fresh water 260 feet.
Gladwin County:					
Gladwin	400	4			
Do	400	6	100	+24	
Gratiot County:					
Alma[9]	2,863			−2	
Ithaca[10]	637	8	50	−72	Several wells; good wa
St. Louis[11]	1,314				Deep well.
Hillsdale County:					
Hillsdale[12]	1,350-1,550				Brine at 1,100 feet.
Houghton County:					
Lake Linden	1,502-1,508	12-8	100		
Huron County:					
Caseville[7]	1,750-1,770				Salt wells.
Do.[13]	1,760-2,270				Do.
Grindstone	1,080				Abandoned.
Do.[13]	(?) 1,000				Salt well.
Harbor Beach[13]	+702				Do.
New River[13]	1,029				Do.
Old Bay Port[13]	2,000				Salt well; never in ope tion.
Pigeon River[13]	1,760				Pigeon River Furn Co.'s salt well (h Lake Huron Iron Co.
Port Austin[14]	1,198-1,225				Salt wells; sweet wate 336 to 1,100 feet.
Port Crescent[13]	1,250				Salt well.
Port Hope[15]	787				Do.
Sandbeach[16]	702				Do.
Do.[17]	1,920				For gas; unsuccessful.
Verona Mills (near)[18]	400	5¼			
Whitecrock[19]	555-1,311				Several salt wells.
Ingham County:					
Lansing "magnetic well."	1,400		1	Flows.	Saline water; temp., 5
Lansing Hotel	740				
Lansing Reform School[20]	506				
Mason (near)[21]	401, 409				
Meridian (near)[22]	514				

[1] Mich. Geol. Surv. Rept., 1881-1893, vol. 5, part 2, p. 53.
[2] Record, Ann. Rept. State Board of Geol. Surv. of Mich., 1901, pp. 230-231.
[3] Record, ibid., p. 227.
[4] Record, Mich. Geol. Surv. Rept., 1900-1903, vol. 8, part 2, p. 196.
[5] Record, State Board of Geol. Surv. of Mich., 1901, pp. 231-232.
[6] Ibid., pp. 228-229.
[7] Record, Mich. Geol. Surv. Rept., 1881-1893, vol. 5, part 2, p. 53, pl. 8.
[8] Ibid., p. 58; 1873-1876, vol. 3, part 1, p. 97.
[9] Analysis, ibid., pp. 45-46; U. S. Geol. Surv. Water-Sup. and Irr. Paper No. 31, p. 83; record, Mich. Geol. Surv. Rept., 1900-1903, vol. 8, part 2, p. 175.
[10] Record, ibid., pp. 63-64.
[11] Mich. Geol. Surv. Rept., 1900-1903, vol. 8, part 2, p. 174
[12] Record, ibid., 1881-1893, vol. 5, part 2, p. 1873-1876, vol. 3, part 1, p. 81.
[13] Mich. Geol. Surv. Rept., 1896-1900, vol. 7, p 2, p. 224.
[14] Record, ibid., 1881-1893, vol. 5, part 2, pp. 76; 1873-1876, vol. 3, part 1, pp. 77-78; analy p. 183.
[15] Ibid., p. 76.
[16] Analysis, ibid., 1873-1876, vol. 3, part 1, p.
[17] Record, ibid., 1891-1893, vol. 5, part 2, pp. 81
[18] Ibid., 1896-1900, vol. 7, part 2, pp. 175-176.
[19] Mich. Geol. Surv. Rept., 1873-1876, vol. 3, p 1, pp. 76-77; analysis, p. 184; record, 1881-1893, 5, part 2, p. 86; 1896-1900, vol. 7, part 2, p. 160.
[20] Record, ibid., pp. 117-118.
[21] Ibid., 1900-1903, vol. 8, part 2, pp. 216, 217.
[22] Ibid., p. 207.

MICHIGAN—Continued.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
.....	498	.....	.....	.....	
.....	400–600	8	Many.	+ 7	No water below 362 feet, temp., 55°.
.....	450	.....	.....	.....	Flow of sweet water at 300 feet.
.....	447	2	.....	− 1¼	
is[2]	905	.....	.....	.....	Salt well.
.....	1,070–1,103	.....	.....	.....	Salt wells.
y[4].....	905	.....	.....	.....	Salt well.
ty:					
.....	2,100–2,455	.....	.....	Flows.	Several wells. Flow of water at 1,050 feet; hot water at 1,820 feet.
.....	2,700	.....	.....	.....	Abandoned.
.....	206–400	10	Many.	- 9	Large water supply; several wells.
ounty:					
o[6].....	2,250	.....	.....	.....	
pids[7]	2,200	.....	.....	.....	Fresh water with gas and brine at bottom.
.....	(?)700	.....	.....	.....	
y:					
.....	1,020	.....	.....	.....	Fresh water at 190 to 200 feet; salt water at 648 to 710 feet.
nty:					
Point (Carp	.....	8	.....	+ 15	
it	700	8	.....	+ 10	Sulphur water 300 feet in rock.
nty:					
.....	1,650	.....	.....	.....	Mineral water at 805 feet; abandoned.
.....	1,800	.....	.....	.....	
"	2,402	.....	.....	.....	
.....	1,700	.....	.....	.....	
.....	+1,275	.....	.....	.....	
ounty:					
.....	550	.....	.....	.....	Gas; abandoned.
nty:					
[14]	919	8	Many.	Flows.	Strong sulphur water.
.....	1,166	.....	.....	.....	
ity:					
mens[16].....	1,060–1,244	.....	.....	.....	Several mineral wells.
.....	1,265	5¼	.....	.....	
more[17]	1,640	.....	.....	.....	
.....	1,600	.....	.....	−600	
nty:					
[19]	1,947–2,270	.....	.....	.....	Numerous salt wells in town and vicinity. Black water at 960. Some oil at 1,905 feet.
.....	2,015	10–5	.....	- 15	2 salt wells.
.....	1,900	.....	.....	.....	4 wells.
[20]	1,972	.....	.....	.....	
::					
n[21].....	2,220	.....	.....	.....	
.....	1,650	.....	.....	.....	
n ¼ mile	2,260	.....	.....	.....	
3					
ity:					
ls	1,360	.....	Many.	- 30	Mineral water.
ounty:					
ee	−400	.....	.....	.....	

ich. Geol. Surv. Rept., 1873–1876, vol. 34–135.
-1893, vol. 5, part 2, p. 57; analysis, . 3, part 1, p. 184.
bid., 1873–1876, vol. 3, part 1, p. 186.
id., p. 79.
-1893, vol. 5, part 2, p. 65, pls. 23–25.
, pl. 26.
, pl. 20.
, pl. 22.
, pl. 1.
nn. Rept. State Board of Geol. Surv. , p. 219.
219–220.
. State Board of Geol. Surv. of Mich.,

[13] Record, Mich. Geol. Surv. Rept., 1900–1903, vol. 8, part 2, p. 218.
[14] Ibid., 1881–1893, vol. 5, part 2, p. 79, pl. 63.
[15] Record, Ann. Rept. State Board of Geol. Surv. of Mich., 1901, p. 228.
[16] Record and Analysis, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, pp. 70–71, pl. 42.
[17] Record, Ann. Rept. State Board of Geol. Surv. of Mich., 1901, pp. 221–222.
[18] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 78, pl. 59.
[19] Ibid., p. 66, pls. 30–32; Ann. Rept. State Board of Geol. Surv. of Mich., 1901, p. 235.
[20] p. 84, pl. 65.
[21] Ibid., p. 66, pl. 27.
[22] Ibid., p. 66, pl. 29.
[23] Ibid., p. 66, pl. 28.

MICHIGAN—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Midland County:					
Midland[1]	1,300–1,325				
Do	400		Many.		
Monroe County:					
Monroe[2]	1,765	8	Several.	+ 4	Well now plugged; water somewhat sulphurous.
Muskegon County:					
Muskegon (vicinity)[3]	+2,050				Ryerson-Hills well.
Do.[3]	1,515				
Do.[3]	1,500				
Do.[4]	1,230				Flows of mineral water at 333 feet and 643 feet.
Do.[5]	2,627				Strong flow of mineral water at 700 feet, brine at 2,400 feet.
Do	2,000				
Oakland County:					
Pontiac[6]	1,505				Salt water at 1,100 feet.
Royal Oak[7]	1,400				
Do.[8]	2,502				
Ogemaw County:					
West Branch (8 miles southwest).[9]	403	6–4			
Roscommon County:					
Roscommon	600				Some oil.
Saginaw County:					
Blackmar	1,764				Salt well.
Carrollton	743–800				Several salt wells.
East Saginaw[10]	806				Salt well.
Melbourne	950				
St. Charles[11]	800–900				Salt wells.
Saginaw	741–830				Numerous salt wells.
Do.[12]	860				
Saginaw (southeast).[13]	1,764				Brine at 350 and 1,655 feet.
Salina[14]	715				
Zilwaukee[15]	800–860				Several wells.
St. Clair County:					
Algonac[16]	1,614				Salt well.
Algonac (5 miles below).[17]	1,727				Do.
Marine City[18]	1,470–1,737				Several salt wells in and near town.
Marine City (city well)[19]	1,777			Flows.	Clear water 1,170–1,370 feet.
Marine City[20]	1,751				Salt well.
Maryville[21]	1,150				Salt water at 745 feet; mineral water 970 and 985 feet.
Port Huron	600	8–6			
Do	728	10–8		19	
Do.[22]	498–785				Gas wells.
Port Huron (12 miles northwest).				Flows.	
Port Huron[23]	1,700				Gas and salt.
Port Huron Deerspring	745			150	Slightly mineral water.
St. Clair[24]	919				Salt wells.
Do.[25]	1,682			300	Salt well.
Do.[26]	1,807				
Do.[27]	1,855				Do.

[1] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 69.
[2] Ibid., p. 70, pl. 41.
[3] Record, etc., Ann. Rept. State Board of Geol. Surv. of Mich., 1901, pp. 233–234.
[4] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 71, pl. 43; 1873–1876, vol. 3, part 1, p. 84.
[5] Ibid., 1873–1876, vol. 3, part 1, p. 85.
[6] Ibid., 1881–1893, vol. 5, part 2, p. 75, pl. 47.
[7] Ibid., p. 79.
[8] Ibid., p. 79, pl. 60.
[9] Ibid., 1900–1903, vol. 8, part 2, p. 158.
[10] Ibid., 1891–1893, vol. 5, part 2, p. 55; 1873–1876, vol. 3, part 1, pp. 94–96, analysis, p. 183.
[11] Ann. Rept. State Board of Geol. Surv. of Mich., 1901, p. 224.
[12] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 79, analysis, ibid., 1873–1876, vol. 3, part 1, p. 182.
[13] Ibid., 1873–1876, vol. 3, part 1, pp. 96–97.
[14] Ibid., 1900–1903, vol. 8, part 2, pp. 175–176.
[15] Analysis, ibid., 1873–1876, vol. 3, part 1, p. 1[illegible]
[16] Record, ibid., 1881–1893, vol. 5, part 2, p. [illegible] pl. 3.
[17] Ibid., pl. 2.
[18] Ibid., p. 67, pls. 33–38.
[19] Ibid., p. 67, pl. 39.
[20] Ann. Rept. State Board of Geol. Surv. of Mich., 1901, p. 241.
[21] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 68, pl. 40.
[22] Ibid., 1873–1876, vol. 3, part 1, p. 77.
[23] Ibid., 1896–1900, vol. 7, part 3, pl. 1.
[24] Ibid., 1881–1893, vol. 5, part 2, p. 79, pl. 62.
[25] Ibid., pl. 61.
[26] Record, etc., Ann. Rept. State Board of Geol. Surv. of Mich., 1901, p. 222.
[27] Record, ibid., p. 241.

MICHIGAN—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
St. Joseph County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Constantine[1]	680				Strong brine at 382 feet.
Do.[2]	+1,080				
Florence	800				Salt wells.
Sanilac County:					
Croswell[3]	675				Waterworks well.
Forestville	505–600				Abandoned and filled up
Lexington (3 miles south).[4]	900				
Marlette[5]	624				
Valley Center[6]	685				
Shiawassee County:					
Corunna[7]	907				
Durand[8]	635				
Owosso[9]	1,000				Brine at 634 feet.
Van Buren County:					
Bangor[10]	1,300				Strong brine flows.
Washtenaw County:					
Ann Arbor[11]	1,326	6¼			
Do.[12]	770 or 775			− 40	
Milan[13]	890				
Ypsilanti[11]	965				
Do	808				
Do	730				
Wayne County:					
Detroit (9 miles northeast).[14]	770				Some gas and water at 165 feet.
Detroit[15]	2,097				
Norris	631				For gas; abandoned.
Trenton[15]	1,370				
Wyandotte[16]	2,500				Abandoned.
Do	600–800				Numerous salt wells.
Do.[15]	1,300				
Wyandotte (near)[17]	1,603				River Rouge Improvement Co.'s well.
New River[18]	1,029				Salt well.

[1] Record, Mich. Geol. Surv. Rept., 1873–1876, vol. 3, part 1, p. 93.
[2] Ibid., 1881–1893, vol. 5, part 2, p. 54, pl. 11.
[3] Ibid., 1896–1900, vol. 7, part 3, p. 11.
[4] Ibid., p. 12.
[5] Mich. Geol. Surv. Rept., 1896–1900, vol. 7, part 3, p. 30.
[6] Record, ibid., p. 11.
[7] Ibid., 1881–1893, vol. 5, part 2, p. 54, pl. 12.
[8] Ibid., 1900–1903, vol. 8, part 2, p. 199.
[9] Ibid., 1873–1876, vol. 3, part 1, p. 97; 1881–1893, vol. 5, part 2, p. 78, pl. 45.
[10] Ann. Rept. State Board of Geol. Surv. of Mich., 1901, p. 214.
[11] Record, etc., ibid., pp. 214–215.
[12] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, pp. 47–49; 1873–1876, vol. 3, part 1, p. 92.
[13] Record, Ann. Rept. State Board of Geol. Surv. of Mich., 1901, p. 219.
[14] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 54, pl. 15.
[15] Record, Ann. Rept. State Board of Geol. Surv., 1901, p. 217.
[16] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 87, pl. 66.
[17] Ibid., p. 218.
[18] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 73; 1873–1876, vol. 3, part 1, p. 77.

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Water resources of the lower Peninsula of Michigan, by A. C. Lane: U. S. Geological Survey Water-Supply and Irrigation Papers No. 30, 97 pages, plates, Washington, 1899.

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Coal of Michigan, by A. C. Lane: Geological Survey of Michigan, 1900–1903, vol. 8, part 2.

Report of the State Board of Geological Survey of Michigan, for 1901, by A. C. Lane.

MINNESOTA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remar
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bigstone County:					
Graceville	460	8–6	40	− 50	2 wells; granit
Do	522	.....	Several.	No flow.	
Blue Earth County:					
Lake Crystal	.....	.....	.....	− 71	
Mankato	2,204	.....	.....	− 90	Unsuccessful.
Do	650	10, 8, 6	500 to 80	+ 40	Several wells; ruginous.
Mankato and vicinity	570–2,240	6–8	.....	.....	Several wells; water rises t
Minneopa Falls [1]	1,000	8–6	Many.	.....	Flow at 540 fee water at 940 f at 940 feet.
Carver County:					
New Germany	410	3	.....	.....	Water at 100 fe
Chisago County:					
Wyoming	505	8–6	Many.	− 12	
Clay County:					
Moorhead [2]	1,901	.....	.....	.....	Water at 120, 1 feet.
Do. [3]	1,425	.....	.....	.....	Water at 120 an
Do	1,820	.....	.....	+ 4	
Cottonwood County:					
Westbrook	600	.....	.....	.....	
Crow Wing County:					
Brainerd	647	.....	.....	.....	
Dakota County:					
Hastings [4]	1,160	.....	100	+ 14	Water slightly
Lakeville	1,085	.....	.....	.....	
Mendota [5]	857	4	10	+ 10	
Dodge County:					
Dodge Center	504	8	80	− 88	Railroad well.
Hayfield	530	.....	None.	.....	
Do	545	10	.....	.....	
Faribault County:					
Blue Earth	1,300	.....	.....	− 30	
Do	1,240	.....	Many.	− 30	
			5	200	First flow at 42 ond flow at 4
Fillmore County:					
Fountain	579	6	20	−225	
Freeborn County:					
Albert Lea	+ 660	.....	.....	.....	
Freeborn	950	.....	.....	.....	Unsuccessful.
Goodhue County:					
Red Wing [6]	500	6	100	+ 75	Flows from 190
Do	1,018	.....	.....	.....	
Hennepin County:					
East Minneapolis [7]	1,421	.....	.....	.....	
Minneapolis	1,431	.....	.....	.....	Several wells
Minneapolis (Lakewood Cemetery). [8]	2,150	.....	.....	.....	ful.
Minneapolis (West Hotel). [9]	622	.....	300	− 24	Water at 168 fe
Minneapolis (C., M. and S. P. R. R. shops).	.....	.....	.....	.....	
Minneapolis (Soldiers' Home).	.....	.....	.....	.....	
Minneapolis (Winslow House).	1,421	.....	.....	No flow.	Abandoned.
Minneapolis	900	.....	.....	.....	
Do	622–2,118	.....	Many.	− 15 to − 50	
Houston County:					
Brownsville [10]	590	.....	1,000	− 13	
Isanti County:					
Dalbo	558	.....	300	.....	
Kandiyohi County:					
Atwater	453	8–6	100	.....	Water-bearing 45,100, and 31
Kandiyohi	450	.....	.....	.....	Unsuccessful.

[1] Record, Minn. Geol. Surv. Bull. 5, Gas in Minnesota, pp. 23–24.

[2] Report on Irrigation, 52d Congress, 1st session, Senate Ex. Doc. No. 41, part 2, 1893, pp. 72–74.

[3] Record, Rept. Spec. Comm. U. S. Senate on Irrigation and Reclamation of Arid Lands, vol. 4, 1890, p. 48; Minn. Geol. Surv. Bull. 5, Gas in Minnesota, pp. 27–31.

[4] Record, Minn. Geol. Surv., 13th Rept., 1884, pp. 56–57; analysis and record, Minn. Acad. Natural Sciences Bull., vol. 3, No. 1, pp. 137–141.

[5] Record, Minn. Acad. Natural Sciences Bull., *vol. 3, No. 1, p. 141; Minn. Geol. Surv., 13th Rept., 1884, pp. 55, 56.*

[6] Ibid., p. 142; Minn. Geol. Surv., 13th pp. 57–58.

[7] Record, Minn. Geol. Surv. Rept., v pp. 154–156.

[8] Record, Minn. Acad. Natural Scie vol. 3, No. 1, pp. 137–138; Minn. Geol. Rept., 1884, pp. 50, 54.

[9] Analysis, ibid., p. 137; record, M Surv., 14th Rept., 1885, p. 11.

[10] Record, Minn. Geol. Surv., 13th Re 59; Rept. Spec. Comm. U. S. Senate on and Reclamation of Arid Lands, 1890, Minn. Acad. Natural Sciences Bull., v p. 142.

MINNESOTA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Kittson County:					
Humboldt[1]	644				Salty water at 170–180 feet.
Do	(?) 1,500				
St. Vincent (2 miles northwest).[2]	1,037				
Lincoln County:					
Tyler	+400				
Do	+600				
Lyon County:					
Cottonwood	465				
Ghent	525				
Heckman (S. W.)	506	2	2	Flows.	
Marshall	400–440	1¼–2	3–10	Flow.	8 wells.
Tracy[3]	724			− 37	
Do	597			−148	
Do	668				
McLeod County:					
Glencoe	1,640	8–6	50	− 85	
Do	1,000		50		
Marshall County:					
Stephen	800				No success.
Meeker County:					
Grove City	700			− 57	
Mower County:					
Austin	750	10–8	220	− 6	Fine water from 600 feet.
Do	550		150	− 9	
Do	580		150	− 9	
Nicollet County:					
St. Peter	498		+200		
Do	450		250		
Nobles County:					
Worthington	600				Unsuccessful.
Do	530				
Olmsted County:					
Rochester	+960				
Pine County:					
Pine City	700	12–4½	75	− 70	
Pipestone County:					
Pipestone	537				
Ramsey County:					
Gladstone	615			− 30	
Mendota	857			Flows.	
St. Paul (G. N. R. R.)	834			− 38	
St. Paul (Elevator Co.)[4]	850			− 35	
St. Paul (St. P. & D. R. R.)	750				
St. Paul Transfer Railroad	575				
St. Paul (West. M. and N. W. R. R.).	1,030			− 24	
St. Paul city well	1,065				
St. Paul (harvester works).[5]	871½				
St. Paul, Wilgus well	625				
St. Paul Fair Grounds	500				
St. Paul, Lake Vaduais	726½			− 11	
St. Paul, White Bear Lake	777			− 18	
St. Paul (Vaduais Lake)	925	10–8		− 6	
St. Paul	575, 840	8		−38 to −40	
South St. Paul	487			− 5	
Do	3,000				For gas.
White Bear Lake	777			− 15	
Red Lake County:					
Redlake Falls	407				
Redwood County:					
Lamberton	400				
Do	+500				
Walnutgrove	400				
Renville County:					
Olivia	+450		None.		
Rice County:					
Faribault	520				Signs of gas.
Northfield	647	8	1,000	− 25	Hard water. Supply is from 300 feet.
St. Louis County:					
Duluth (12 miles west)[6]	1,507½	8–5½		− 40	Mineral water at 1,225 feet.
Fond du Lac	1,508			−10±	Salty water; bored for gas.
Tower (2 miles east)	400	1½	Many.		Diagonal drill hole in gneiss.

[1] Record and analysis, Minn. Geol. Surv., 13th Rept., 1884, pp. 42–47.
[2] Record, ibid., 14th Rept., 1885, p. 15.
[3] Ibid., pp. 351–352.
[4] Ibid., 13th Rept., 1884, p. 63; Minn. Acad. Natural Sciences Bull., vol. 3, No. 1, p. 140.
[5] Record, Minn. Geol. Surv., 13th Rept., 1884, pp. 59–63; Minn. Acad. Natural Sciences Bull., vol. 3, No. 1, p. 140.
[6] Ibid., Bull. 5, Gas in Minnesota, pp. 31–35.

MINNESOTA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Scott County:					
Belleplaine	710				
Jordan	(?) 650				
Merriam Junction	661			+ 6	
Sherburne County:					
Elk River	513		Many.	+ 4	Several wells in vici only flow is at 308
Sibley County:					
Bismark	407		1		
Henderson	750				
Do	707	10–8	400	+ 70	Temp., 50°.
Winthrop	413				
Steele County:					
Owatonna	640	8	250	− 8	
Stevens County:					
Scott	+400				No water.
Swift County:					
Benson	478				
Do	650				
Traverse County:					
Brown Valley[1]	465				
Do	425, 485				
Wheaton	438				
Wabasha County:					
Lake City[2]	820				
Plainview	690	12	100		
Waseca County:					
Waseca	1,157	10–8	200	−120	
Washington County:					
Stillwater[3]	3,500	5			For gas, unsuccessfu ter at 162 and 30 some salt water a feet and some g 2,250 feet.
Watonwan County:					
St. James	501	10–8	300	− 27	Hard water
Do	541	8		− 28	
Wilkin County:					
Campbell	451				
Rothsay	560				
Winona County:					
St. Charles	944			− 60	
Winona	478	6	500	− 10	Temp., 54°; cased 17
Do	515		180		
Do	+485				
Wright County:					
Monticello	500			− 18	Good water.

[1] Record, Minn. Geol. Surv., 14th Rept., 1885, p. 14; Rept. Spec. Comm. U. S. Senate on Irrigation and Reclamation of Arid Lands, vol. 4, 1890, p. 48.

[2] Ibid., 13th Rept., 1884, p. 58; Minn. Acad ural Sciences Bull., vol. 3, No. 1, p. 142.

[3] Ibid., Bull. 5, Gas in Minnesota, pp. Am. Geol., vol. 3, p. 343.

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Minnesota Geological Survey, Fourteenth Annual Report, for 1885, part 1 N. H. Winchell, 165 pages, St. Paul, 1886.

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Natural gas in Minnesota, by N. H. Winchell: Minnesota Geological Survey B tin No. 5, 39 pages, St. Paul, 1889.

Report of the Special Committee of the United States Senate on the Irrigatio Reclamation of Arid Lands, vol. 4, 386 pages, Washington, 1890.

MISSISSIPPI.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Adams County:					
Natchez	430–517	6	50	−160and−8	2 wells.
Bolivar County:					
Cleveland	1,000	3,4	75–100	Flow.	Do
O'Reilly	1,002	4	100	Flows.	
Carroll County:					
Carrollton	1,250	4	.....	.....	
Do	400	4	62	Flows.	
Chickasaw County:					
Houston	1,500	3	Few.	−50	
Okolona	550	6	138	−80	
Do	600	.....	.....	−65	
Clarke County:					
Barnett	600	6	.....	.....	
Enterprise	400	3	.....	.....	
Shubuta	400–422	2–6	20–40	+15–30	Several wells.
Clay County:					
West Point	560	3	.....	−1	
Coahoma County:					
Eaglesnest	825	1¼	8	Flows.	
Jonestown	800	2	8	Flows.	
Lyon	975	4	22	+35	
Copiah County:					
Wesson	1,300	.....	.....	.....	Unsuccessful.
Do	1,400	.....	.....	.....	
Hancock County:					
Bay St. Louis	400–760	4½–2	100–5	Flow.	Many wells; temperature of deeper wells, 78°.
Do	420–750	2–3	100–5	+17 to +42	Several wells.
Do	897	3	225	Flows.	Water at 690 feet flowed 50 gallons a minute; principal flow at 818 feet.
Logtown	620	2¼	60	+25	
Pickayune	500	2	27	+25	
Waveland	432–461	2½–3	25–30	+15–28	
Do	775	3	165	Flows.	Water at 350 and 700 feet.
Harrison County:					
Biloxi	800	.....	.....	.....	
Do	414–920	2–4½	35–450	+20 to +80	Many wells.
Gulfport	540–960	3–5	60–175	+25 to +80	Several wells.
Do	700	4½–2	80	+25	Temp., 71° ±.
Handsboro	500–700	2½–3	60–175	+15–20	3 wells.
Howison	1,500	2	.....	.....	
Longbeach	580, 600	2¼	60, 70	+25 to +35	2 wells.
Mississippi City	514–860	2–4½	50–450	+0 to +80	
Do.[1]	925	.....	200	Flows.	60-gallon flow at 600 feet.
Do.[1]	850	3	80	Flows.	
Pass Christian	420–1,020	2–3	25–250	+25 to +89	Many wells.
Pass Christian (3 miles east).	747	3	225	Flows.	Water stratum from 628 to 747 feet.
Saucier	720	3	.....	.....	
Ship Island (quarantine).[1]	730	.....	.....	Flows.	
Ship Island (lighthouse).[1]	750	.....	.....	Flows.	
Wortham	836	4	75	−15	
Do	590	3	100	Flows.	Water at 110 and 500 feet.
Hinds County					
Jackson	1,200	.....	Many.	.....	
Do	604	.....	Many.	.....	
Holmes County:					
Tchula	800	.....	.....	Flows.	2 wells.
Do	456	2	.....	−16	
Do	470	.....	.....	Flows	
Do	770	2–2	200	.....	
Do	1,125	4–2	130	−85	
Jackson County:					
Fontainebleau	625, 720	2¼	60, 70	−40 to −50	2 wells.
Mosspoint	500–1,550	2,–4	25–400	−20–50	3 wells.
Do	790	3	135	.....	
Ocean Springs	520–1,200	2,–4	25–250	−0–80	
Scranton	774	6	700	−45	Temp. 74°.
Do	750	3	.....	Flows.	
Do	780	6	.....	.....	
Do	727	2	.....	.....	
Do	720	2,–6	60, 150	−30 to −43	2 wells.
Jones County:					
Ellisville	1,160	3	.....	.....	No water below 650 feet.
Do	1,300	6	.....	20	
Lafayette County:					
Oxford	400	.....	.....	.....	

[1] La. Geol. Surv. Rept., 1902, p. 259.

MISSISSIPPI—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Lauderdale County:					
Meridian	680, 905	2, 3	.....	−20 to −25	2 wells.
Lee County:					
Verona	400	6	.....	−60	
Leflore County:					
Greenwood	400	.....	.....	+40	3 wells.
Do	506	6	400	−45	
Do	400	.....	.....	+40	20 wells in adjoini gion.
Do	490–650	4	250, 275	+0 to +40	3 wells.
Do	700	.....	.....	Flows.	
Ittabena	450–597	2–3	60–150	+0 to +35	3 wells.
Lowndes County:					
Artesia (44½ miles south)	700	4–3	10	−90	
Columbus	400	.....	Each 80	Flow.	2 wells; temp., 70°
Do	682	4	.....	+ 6	
Madison County:					
Canton	1, 021	8–3	90	+10	Temp., 74°.
Do	1, 020	4	170	+19	
Do	850	6	88	+16	
Ford	450	6	.....	−40	
Revive	720	.....	.....	−20	
Marion County:					
Columbia	500	3	25	Flows.	
Monroe County:					
Gattman	623	6	15	+27	
Montgomery County:					
Winona	400	10–6	100	−75	
Noxubee County:					
Bigbee Valley	±500	.....	.....	Flow.	
Brookville	680	.....	10	−75	
Cliftonville	±500	.....	.....	Flow.	3 wells.
Cooksville	500	6	.....	−30	
Macon	763	.....	.....	Flows.	2 wells.
Do	750, 800	3–4	5	−14 to +8	3 wells.
Prairie Rock	±600	.....	.....	Flows.	Several wells.
Ravine	700	.....	10	− 25	
Shuqualak	950	6	.....	− 25	
Oktibbeha County:					
Longview	936	10	25	− 5	
Starkville	900, 908	8	145	−129 −130	2 wells.
Perry County:					
Bonhomie	650	.....	.....	− 30	
Quitman County:					
Belen	724–860	2–3	20–60	+0 to +50	
Riverside	636	2	60	+ 40	
Scott County:					
Forest	520	.....	.....	− 90	Water at 220 feet house well.
Sunflower County:					
Doddsville	700	.....	.....	Flows.	
Indianola	800	.....	.....	.....	Unsuccessful.
Do	1, 250	.....	.....	Flows.	
Moorhead	950	3	.....	+ 50	
Do	700–800	.....	.....	Flow.	
Ruleville	700–800	.....	.....	Flow.	
Tippah County:					
Ripley	600	10–8	.....	−25	
Warren County:					
Vicksburg	1, 060	.....	Few.	Flows.	
Do	1, 100	10	.....	.....	Small flows; sli brackish; temp.
Do	900	.....	.....	.....	Abandoned.
Washington County.					
Greenville	500	6	300	− 5	4 wells.
Wayne County:					
Waynesboro	+415	.....	.....	.....	
Do	520–525	4	20–40	+ 10	3 wells.
Yazoo County:					
Mechanicsburg	620	.....	.....	− 40	
Satartia	588	3	15	+ 12	
Yazoo City	635	.....	.....	+ 20	
Do	500	3	.....	−140	
Do	475	4	40	+ 5	2 wells.
Do	740	.....	.....	Flows.	
Do	800	.....	.....	Flows.	
Do	1, 254	.....	.....	Flows.	
Yazoo City (18 miles southeast).	588	.....	.....	−130	
Yazoo City (25 miles southwest).	588	2	14	+ 12	Temp., 70°.
Yazoo City (4 miles west).	696	2	.....	+ 9	

MISSOURI.

ion.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
.....	1,300	.....	.....	.....	
y:					
.....	678	8–6	.....	− 16	Prospect hole for coal; water at 143 feet.
y:					
.....	588	8	10	−100	
.....	1,125	8	70	.....	
.....	1,100	5¼	.....	− 80	
.....	±1,800	.....	.....	.....	For oil or gas, unsuccessful. Salt water.
.....	415	.....	.....	−155	
.....	1,000	6	Many.	−150	Good water; abandoned.
.....	+2,000	.....	.....	.....	
ity:					
.....	1,000	6	.....	.....	Prospect for coal.
.....	1,300	6	.....	.....	Do.
.....	1,805	6	.....	.....	Temp., 82°; water mineral.
5 miles east).	500	6	Few.	.....	
.....	600	8–6	.....	− 10	
y:					
.....	457	.....	.....	.....	
.....	+1,350	.....	.....	.....	
.....	?500	.....	Many.	− 30	
.....	1,100	.....	.....	.....	
ty:					
.....	1,282	10	Many.	Flows.	
.....	750	8	30	− 70	
County:					
.....	1,295	.....	.....	.....	
.....	531	4¼	Many.	− 3	Sulphur water; not in use.
.....	495	.....	.....	.....	
.....	675	.....	.....	.....	
.....	1,000	.....	.....	.....	
orings.....	1,400	8	.....	− 28	Sulphur water.
y:					
.....	1,505	6–4	7	Flows.	Mineral water.
orings.....	1,370–1,460	.....	.....	.....	
ty	1,365	.....	.....	.....	
.....	403	6	.....	− 78	Water strongly mineral; abandoned.
ty:					
miles south).	1,200	.....	.....	To surface.	Water also at 20, 240, and 800 feet.
y:					
.....	910	4	7	+ 10	
.....	755	6	750	.....	Water at 610–620 feet.
:					
.....	740	.....	Many.	.....	
y:					
.....	654	3¼	5	Flows.	Temp., 47°.
.....	650	8	200	+ 20	
.....	850	8	175	+ 20	
.....	900	10	400	+ 20	
.....	900	6	125	+ 20	
.....	800	8–5¼	400	+ 10	Water also at 310 and 425 feet.
.....	913	.....	2,700	.....	Temp., 64°.
:					
.....	1,008	3	Many.	.....	
.....	900	.....	10	.....	
:					
ew	645	6	.....	−509	
.....	575	10	100	− 40	
near).....	663–400	.....	.....	.....	Several prospect holes.

, Geol. Surv. Rept., vol. 3, pp. 96–97
87, 118–119

[3] Ibid., pp. 120–121.
[4] Ibid., p. 71.

MISSOURI—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Jackson County:					
Kansas City[1]	1,000–425			— 30	Several test boring gas; water from 3 feet, 590 feet, an feet; brackish an phur water.
Do	1,000–1,622				
Do	908				Temp., 65°; principa ter supply at 815 water also at 86 ar feet.
Kansas City (Swift & Co.)				—119	
Lisle	405				No water.
Jasper County:					
Carterville	643		Many.	— 70	
Do	800	6	10	—140	
Do	799	5¾	15	—115	
Carthage[2]	2,005				To granite.
Do	1,800	8			
Joplin	1,375	6	30	— 80	Ferruginous water.
Do	1,400	6	80	— 80	
Do	908	6¾	170	—120	
Prosperity	998	10–6	50	—115	
Webb City	500	7¾		— 20	Several water horiz
Do	827	10	+8	— 75	
Do	854	6	+60	—100	
Laclede County:					
Lebanon[3]	1,002	8	1	—200	Water at 135 and 75
Do	453	6¼	35		Water at 380 and 42
Do	1,000	6	Many.	—360	
Lafayette County:					
Concordia	+200				
Higginsville	1,512	12–5	30	— 80	
Lewis County:					
Lagrange[4]	840		60		Brackish.
Do	850	8	Several.	Flows.	
Linn County:					
Brookfield	451		30	—200	
Do	570		Many.		
Livingston County:					
Avalon	406		Few.	— 60	
Avalon (northeast of)	700		Few.		
Cavendish	400		None.		
Chillicothe	700				No water.
Do	539		Many.	— 90	
Do	481		2	Flows.	
Do	1,101			— 70	
Do	515				Very little water.
Do	+700		Many.	8	
Do	469		Many.	— 90	
Dawn	+433		Many.	— 65	
Dawn (near)	421		Few.	Flows.	
Springhill (near)	414			— 70	
Utica	422	6–4	Several.	+ 10	
McDonald County:					
Galbraith Spring[5]	804		Many.		
Lanahan	1,428	6	50	Flows.	Sulphur water.
Madison County:					
Mine Lamotte	670	2	4	Flows.	
Maries County:					
Steen Prairie					
Marion County:					
Philadelphia	470, 558		300	6	2 wells; much water oil.
Hannibal	1,340				
Mercer County:					
Halfrock	537		None.		
Princeton	501		None.		
Topsy	+ 400				
Miller County:					
Eldon	595			— 80	
Montgomery County:					
Montgomery City	1,500	10–5¾		— 30	
Do	600	6	70		Temp., 58°.
Newton County:					
Diamond					
Granby (sec. 6)	876	8	600	— 10	
Racine (4 miles north)	1,244	9		— 80	

[1] Analysis, U. S. Geol. Surv., 17th Ann. Rept., part 2, 1895–96, p. 827.
[2] Record, Mo. Geol. Surv. Rept., vol 7, p. 405.
[3] Record, Geol. Mo., by Broadhead, part 2, p. 86.
[4] Analysis, Mo. Geol. Surv. Rept., vol. 3 141–143.
[5] Ibid., pp. 117–118.

MISSOURI—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Pemiscot County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Caruthersville	428	5	350	− 10	
Pettis County:					
Sedalia (2 miles south)	1,500	9–6			Prospect hole; full of water.
Pike County:					
Louisiana [1]	1,275		Many.	Flows.	Temp., 64.2°.
Do	1,350			+ 40	
Putnam County:					
Unionville	700				Some water at 215 feet; abandoned.
Randolph County:					
Jackson	460				
Moberly	510	8	300	−200?	2 wells.
Do	2,100			− 70	Largest flow at 632 feet; salt water at 870 feet; magnesium at 1.180 feet, and very salt water at 1,215 feet.
Randolph Springs [2]	969	4	120	Flows.	Temp., 58°; mineral water.
Reynolds County:					
Munger	449				
St. Charles County:					
St. Charles	1,276	6	40	− 40	
St. Charles (2 miles west)	1,365				
St. Clair County:					
Appleton City	1,295				
Osceola	500	7¼		− 20	Several water horizons.
Do	500	8	Many.	− 75	
Ste. Genevieve County:					
Ste. Genevieve	700–800				For oil or gas; unsuccessful.
St. Francois County:					
Farmington (near)	442 650	2¼			Prospect borings for lead.
St. Louis County:					
Clayton	1,060				
St. Louis	400–700		30	−200	Many wells.
St. Louis (asylum)	3,843¼		Few.		Temp., 105°; salty water.
St. Louis (Belcher) [3]	2,176		1		3 per cent salt at 1,231 feet; temp., 66°.
Do. [4]	2,199	9–3¼	75	Flows.	Temp., 73.4°; water from 1,515 feet.
Do. [5]	+1,590	6–3¼			Gas at 466 feet; salt water at 520 feet; temp., 69° at 1,351 feet.
St. Louis (power house)	1,474			− 70	
Near Chain of Rocks.	735	6	70	− 45	Water slightly sulphurous.
St. Louis	1,000				2 wells.
Do	485	6	175	− 60	
Do	518	5¼–4¼	15		Water.
Do	650	8–5¼			Dry hole.
Shannon County:					
Bartlett	+400				
Do	740	6	70	−340	
Birchtree	+400				
Winona	700	8.4–3	Many.	−400	2 wells.
Shelby County:					
Bethel (4 miles north)	450	6	1	− 90	
Epworth	410		1	− 80	
Oakdale	+400				
Sullivan County:					
Galt station	426			−100	
Vernon County:					
Nevada [6]	800		165	Flows.	
Nevada	860	10	560	− 80	
Do	1,001	8	700	− 80	Flows to +9 feet when not pumped.
Do	900		Many.	Flows.	
Warren County:					
Truesdail	+400				
Warrenton	450	6–4	1	150	3 wells.
Do	400	6		−150	
Wright City	406	6		− 70	Fine water.
Washington County:					
Barytles	495				Abandoned.
Potosi	522–585	2		− 66	3 wells.
Do	414			− 2	

[1] Record and analysis, Geol. Mo., by Broadhead, part 2, p. 86.
[2] Analysis, Mo. Geol. Surv. Rept., vol. 3, pp. 73–74.
[3] Ibid., pp. 79–81.
[4] Analysis and record, St. Louis Acad. Sci. Trans., vol. 1, pp. 80–86, pl. 5.
[5] Record, Am. Jour. Sci., 2d ser., vol. 15, pp. 460–46[illegible]
[6] Analysis, Mo. Geol. Surv. Rept., vol. 3, pp. 1[illegible] 122.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN MISSOURI.

Report on the mineral waters of Missouri, by Paul Schweitzer: Missouri Geological Survey, 1890–1892, vol. 3, 256 pages, Jefferson City, 1892.

MONTANA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Carbon County:					
Bridger (near)	1,500	14-4¾			In progress; brackish water at 450 feet that came to top of well; flows at 1,000 and 1,500 feet, which come to top of well; water at 1,500 feet; strongly charged with sulphuretted hydrogen gas.
Cascade County:					
Great Falls	+500				In progress; gas at 300 feet; indications of oil farther down.
Chouteau County:					
Chinook[1]	956			−50	Water also at 112, 220, 540, and 620 feet.
Fort Assinniboine	1,950				Small flow of gas; no water below 65 feet; all clay.
Fort Benton	502				Small flow of gas at 300 feet; indications of oil at 502 feet.
Custer County:					
Fort Keogh	811		15	Flows.	
Miles City	472	4-2¼		Flows.	
Do	481	4-2¼		Flows.	
Do	456	4-2¼		Flows.	
Miles City (court-house)	509	4-2¼		Flows.	
Miles City[2]	456		5	+16	Temp., 57°.
Do	535	4	2		
Miles City (35 miles west)	420	4-2¼		Flows.	
Miles City	452-511			Flow.	5 wells.
Do	479	9-2¼		Flow.	
Miles City (10 miles east)	553			Flows.	
Miles City (Reform School).	507			Flows.	
Rosebud	485-502	4-2¼		Flows.	3 wells.
Dawson County:					
Glendive (court-house)	500				Unsuccessful.
Flathead County:					
Kintla Lake (near)	1,405				Strong flow of water and gas necessitated discontinuance of drilling until heavier tools could be procured.
Gallatin County:					
Bozeman	600				Bored for oil; unsuccessful.
Lewis and Clarke County:					
Helena	1,002				
Do	1,023				Good flow, abandoned.
Do	900			−100	
Teton County.					
Chief Mountain Lake	1,200				Lubricating oil well, 30 barrels a day; just north of United States boundary line.
Yellowstone County:					
Billings	1,000				All in shale
Junction	500			Flows.	Small flow also at 144 feet.

[1] Report on Irrigation, 52d Cong., 1st sess., Senate Ex. Doc. 41, part 2, 1893, pp. 72-73.

[2] Record, ibid., pp. 73, 96.

NEBRASKA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Adams County:					
Hastings[1]	1,145			− 40	Salt water at 940 feet.
Banner County:					
Harrisburg	470–790				Several unsuccessful borings.
Boone County:					
Albion	827	6		− 9	Water at 125 feet; drill stuck in soapstone at 825 feet; boring discontinued.
Do	1,700				For coal; unsuccessful.
Boyd County:					
Lynch	797	4¼	465	Flows.	Strong pressure; power used for flour mill.
Do	923	8	3,100	Flows.	New well; strong pressure.
Tp. 34, R. 8, sec. —	760	3	100	Flows.	Boyd.
Buffalo County:					
Kearney	2,600				Unsuccessful.
Cass County:					
T. 10, R. 13, sec. 34	480	3			Water at 30 feet.
Do	500	4			Salt water at 470 feet.
Cedar County:					
T. 32, R. 1 E	535	3	2		For watering cattle.
T. 32, R. 2 E	400–500	2	2–60	Flows.	Temp., 60°.
Do	500–600	2	Few.	Flows.	Temp., about 60°.
T. 32, R. 3 E	400–600	2	1¼–31¼	Flow.	Temp., 58° to 60°; 600-foot well ceased flowing.
T. 33, R. 1 E	400–630	1¼–2	5–25	Flows.	Pressure variable; temp., about 60°.
T. 33, R. 1 W	400–648	1¼–3¼	7–44	+19–+35	Temp., 58° to 60°.
St. Helena[2]	466		Many.	Flows.	Water at 400 feet.
Chase County:					
T					
T. 6, R. 39, sec. 21	500	2			Water at 22 feet.
Cherry County:					
Southwestern portion	475	2	12	+ 11	Abbott well.
	480	1¼		+ 10	Plumer well.
	500	1¼	12	+ 12	Do.
	500	1¼	15	+12to+ 15	Gentry well.
Custer County:					
Cliff	400–485	3¼–1¼	Many.		Several wells; no flows.
Dawes County:					
Marsland (one-fourth mile east).	927	5		− 50	Town well.
Chadron	400 1,100 1,800				3 wells; unsuccessful.
Chadron (12 miles northeast).	1,000				Failed to reach Dakota sandstone.
Dixon County:					
Ponca	498				
T. 31, R. 6, sec. 20	484	3	Few.	− 3	Flowed 3 weeks.
T. 32, R. 5, sec. 32	400	2	3	+ 31	Flowed 50 gallons originally.
Douglas County:					
Omaha—					
Clark and Sixteenth streets.	664		125	+ 52	Temp., 58°.
Grant smelter	1,044	10–6	800	+ 65	Flows at 650 and 800 feet; temp., 55°.
Thirty-second and O streets.	1,800		Many.	− 70	
Elmwood Park	1,845			− 50	
Hanscom Park	1,120		Many.	−138	
Riverview Park	1,065		600		Temp., 62°.
Willow Spring	1,700		Many.	+100	
Exposition grounds	1,115		Many.	Flows.	First water at 700 feet; temp., 60°.
A. Booth & Co	1,094				
Seymour Park	1,303		500	+ 35	
Pickards	1,383		70	Flows.	Temp., 62°; abandoned.
Krug brewery	1,310		Many.	−142	
Power house, Nineteenth street.	840				
Cortland Beach	998	6–5		+ 40?	
T. 15, R. 12 (7 miles west of Omaha).	1,430	10	Many.	+ 35	Said to flow over a million gallons a day.
Furnas County:					
Arapahoe	700			No flow.	
Gage County:					
Beatrice	1,200		Few.	Flows.	
Beatrice (near)	1,260	6		Flows.	
Do	1,240	6		Flows.	Water at 50 feet.

[1] Record, U. S. Geol. Surv. Water-Sup. and Irr. Paper No. 12, pp. 37–38.

[2] Record, Am. Assoc. Adv. Sci. Proc., vol. 1886, pp. 217–219.

NEBRASKA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Grant County:					
Hyannis	400				2 wells.
Holt County:					
O'Neill	1,300				Unsuccessful.
Hooker County:					
Farm of E. Demerit	1,200			Flows.	
Howard County:					
Dannebrog[1]	1,011				Unsuccessful.
Jefferson County:					
T. 2, R. 2, sec. 4	500	4		+ 4	Seven borings strong salt wa to 238 feet; ter
Johnson County:					
Tecumseh	520				Boring made for successful; no ported.
Keith County:					
T. 12, R. 37, sec. 8					Water at 176 and 137 feet of wat
T. 13, R. 35, sec. 5	525	6	500		Water at 7 feet.
T. 14, R. 40, sec. 18[2]	421	3			Unsuccessful or of sand.
T. 14, R. 41, sec. 2	407	3¼	2		Water at 385 fee
Do[2]	402	2			Bad workmansh ed well usel medium hard.
Kimball County:					
T. 9, R. 3, sec. 29	460		Many.		No flow.
Knox County:					
T. 31, R. 6, sec. 29	770	2	14	+ 78	Pressure greatl lished.
T. 32, R. 2	420		50		
T. 32, R. 6, sec. 12	548	2	240	+188	Largest flow at
Niobrara Mill	656	8	1,900	+218	Pressure 120 p 1896.
T. 32, R. 6, sec. 16	656	8	2,500		2 wells; water a 600 feet.
Do	656	8	Many.		Water at 625 fee
Packing house	600	2	280	+246	Pressure dimini ing to leak.
T. 32, R. 7, sec. 21	500	2			In progress; no pected.
T. 33, R. 2, sec. 13	700	2	Many.		No flow; 200 f Missouri Rive
T. 33, R. 2, sec. 15	405, 425	2	9	+ 32	2 wells; consider age.
T. 33, R. 2, sec. 16	400	2	9	+ 25	
T. 33, R. 2, sec. 17	400	2	3	+ 57	Leaks.
T. 33, R. 2, sec. 19	550	2	10		
T. 33, R. 2, sec. 20	650	4¼	30	+137	Leaks; present low.
T. 33, R. 3, sec. 13	504	2	2	Flows.	On high land.
T. 33, R. 3, sec. 15	400	2		Flows.	
T. 33, R. 3, sec. 16	400	2	8	Flows.	Leaks.
Santee Agency	+600	6		Flows.	Do.
Santee Agency Mission[3]	603	2¼	20		
Santee Agency School	604	3		Flows.	143 feet above River.
Do	740	8	1,699	+126	105 feet above River; press yield diminisl
T. 33, R. 8, sec. 18	700	2	420	+172	3 flows; pressu diminished, leakage.
Do	760	3	420	Flows.	
Lancaster County:					
Lincoln[4]—	985			−100	Salt water at 24 feet.
Sanitarium[5]	570			+ 34	
Public square	1,050		Many.	Flows.	Salt water at 560 feet.
Burlington Beach	2,463		Many.	Flows.	Salt water at 82
Madison County:					
Norfolk	472			−100	
T. 23, R. 4	335	6	Many.	−275	
Tilden	+400	4		− 90	
Merrick County:					
Silver Creek	1,700			− 19	

[1] Record, U. S. Geol. Surv. Water-Sup. and Irr. Paper No. 12, p. 47.
[2] U. S. Geol. Surv. Bull. No. 131, 1895, p. 96.
[3] Record, 51st Cong., 1st session, Senate Ex. Doc. No. 222, pl. op. p. 55.
[4] Record, Am. Assoc. Adv. Sci. Proc., 218.
[5] Descriptions, records, etc., U. S. G Water-Sup. and Irr. Paper No. 12, pp. 2 Assoc. Adv. Sci. Proc., vol. 35, p. 218; Geog. and Geol. Nebr. (Aughey), 1880.

NEBRASKA—Continued.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
nty:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
le[1]	1,001				Test boring for coal; flow of salty water at 242 feet.
nty:					
are	535			No flow.	
City	448	4		− 6	Mineral water.
	1,000—1,200				Several deep wells in progress.
	570				Salt water.
ity:					
	562	6			Unsuccessful.
y:					
	580	4			Unsuccessful.
ounty:					
	405	6			Some water at 375 feet.
County:					
y	1,300				
niles west)	1,370				Coal prospect.
y:					
	1,450	10		−760	Pressure, 15 pounds.
nty:					
northwest of)	451				
County:					
	300				Vigorous flow for short time, but soon choked up.
ity:					
	610				No flow; abandoned.
unty:					
eastern portion	300	1¼	10	+ 10	Richard's well.
	582				Failure; water at 180 to 182 feet.
ity:					
	725				Some water; no flow.
nty:					
it	409				Iron ore at 375 feet; oil at 379 feet.
nty:					
	905				Failure.
st south of)[3]	590	4		+ 16	Russian mill well; abandoned.

[1] Am. Assoc. Adv. Sci. Proc., vol. 35, pp. 217-219.
[2] Record, U. S. Geol. Survey Water-Sup. and Irr. Paper No. 12, p. 31.
[3] Ibid., pp. 33-34.

IPAL PUBLICATIONS RELATING TO DEEP BORINGS IN NEBRASKA.

ound waters of a portion of southeastern Nebraska, by N. H. Darton: ates Geological Survey, Water-Supply and Irrigation Paper No. 12, 56 s, plates, Washington, 1898.

inary report on the geology and water resources of Nebraska west of the ed and third meridian, by N. H. Darton: United States Geological Survey, Annual Report, 1896-1897, part 4, pages 719-785, Washington, 1899.

a Geological Survey, Report State Geologist E. H. Barbour, vol. 1, Lincoln,

States Geological Survey Bulletin No. 131, page 96, Washington, 1895.

ary report on the geology and underground water resources of the central ns, by N. H. Darton: United States Geological Survey Professional Paper ashington, 1905.

NEVADA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Lander County:					
Battle Mountain[1]	800	6			Strong flow.
Do.[2]	650		58		Several flowsatle
Lincoln County:					
Dalamar	800				Unsuccessful.
Ormsby County:					
—[1]	400	6-7	5		Several wells.
White Pine County:					
Ely	600		Several		
Churchill County:					
Vail Ranch	400			No flow	
Sierra Valley[2] (?)	1,132	3	30		Hot Water.

NEW HAMPSHIRE.

Grafton County:					
Warren	492	6	3		
Hillsboro County:					
Greenville	410	6	20	−90	
Manchester	630	8	Few.	No flow.	
Merrimac County:					
Concord	1,825	6	Few.	−16	Well abandoned 935 feet
Strafford County:					
Dover	400	6	100	No flow.	
Sullivan County:					
Plainfield	1,104	6		− 6	

NEW JERSEY.

Atlantic County:					
Atlantic City[3]	578	8		Flows.	Water at inter 328 to 554 feet.
Do	2,306			Flows.	But little water to 860 feet.
Do	809	6		Flows.	
Do.[4]	830-850	6		Flow.	5 wells.
Do	1,150	8-6		+ 5	No water 960 to
Do	960	6-4½		Flows.	Pumps 200 gallo
Do	554	8	50	Flows.	
Do	735	6-4½		Flows.	Pumps 200 gallo
Do	720	6		Flows.	Pumps 250 gallo
Do	780	6-4½	150	Flows.	
Do	763	8	Many.	Flows.	
Do	1,398	10-4½			No water at th several flows a
Do	805	8-4½	40	Flows.	Pumps 125 gallo
Do	843	6	100	Flows.	
Do	813	6	105	Flows.	Pumps 400 gallo 60°.
Do	805	8		Flows.	Pumps 200 ga minute.
Do.[5]	1,400	10-4			No water at th several flows a
Do	816	6	250		Pumped.
Do.[6]	826	6	100		Do.
Brigantine[7]	798	6	100	Flows.	
Longport[8]	803	6	180	Flows.	Temp., 66°
Smiths Landing[9]	715	6	100	−17	
South Atlantic City	810	8	40	Flows.	
Ventnor[10]	813	6		Flows.	
Bergen County:					
Fort Lee	1,000				Through trap i no water.
Burlington County:					
Burlington	675				
Columbus[11]	715				
Jobstown[12]	715				

[1] Report Surveyor-General and State Land Register, 1891-92, p. 72.
[2] Ibid., 1889-90, p. 82.
[3] Records, etc., of many wells at Atlantic City: N. J. Geol. Surv. Repts. for 1887, 1888, 1889, 1892, 1893, 1894, 1895, 1896, 1897, 1898, and 1899.
[4] N. J. Geol. Surv. Rept., 1900, pp. 115-118.
[5] Record, N. J. Geol. Surv. Rept., 1890, p. 90.
[6] N. J. Geol. Surv. Rept., 1903, p. 85.
[7] Record, ibid., 1895, pp. 77-79.
[8] Ibid., pp. 83-85.
[9] Ibid., 1889, pp. 104-106.
[10] Ibid., 1898, pp. 76-78.
[11] Ibid., 1892, pp. 305-306.
[12] Ibid., 1897, pp. 247-248.

NEW JERSEY—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Burlington County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Moorestown[1]	457				
Mount Holly[2]	562				Small supply.
Seven Islands[3]	408	6-3	70	Flows.	
Camden County:					
Asyla[4]	457	8-6	200	− 25	Pumped.
Cape May County:					
Avalon[5]	925	10-4½	75	8	
Cape May[6]	1,313	10-2½		− 4	Large supply, 90 to 130, 285 to 300, and 585 to 600 feet; no water below 600 feet.
Cape May Point[7]	700				
Ocean City[8]	800		140	Flows.	
Do.[9]	821	8	Many.	Flows.	
Do.[10]	760		Many.	Flows.	
Do	830	8-6	Many.	Flows.	
Do	816	6	250		Pumped.
Do.[11]	812	4½	150		Do.
Sea Isle City[12]	464			Flows.	
Do.[13]	854	6	160	+ 14	
Wildwood	655		300	Flows.	Temp., 63°.
Do.[14]	1,244		10	Flows.	Temp., 67°; water at 625, 750, 843, and 1,185 feet.
Cumberland County:					
Bridgeton[15]	990	8		− 2	Large supply.
Greenwich[16]	690	4-2½			No water found.
Millville[17]	685				No water below 212 feet.
Essex County:					
Brookdale[18]	712	4½	174		
Caldwell	875				
Franklin[19]	400	8	125		
Harrison	400		100		In soft shale.
Milburn	800	8	100		
Montclair (Mount Prospect).	510	7¾	45		Soft water.
Newark (Balentine's)	529		150		
Do.[20]	450	8	200		
Newark (Celluloid Co.)	827	10	200	No flow?	
Newark (Citizens' Gas Co.)	600		50		
Newark	615	8	556		
Newark (smelter)[21]	500	8	500		
Gloucester County:					
Glassboro[22]	511				
Harrisonville[23]	402				
Pitman[24]	507			−140	Good supply.
Sewell	420	3			Water also at 72, 381, and 395 feet.
Hudson County:					
Bayonne	600		Few.		
Ellis Island	1,400	8			Water brackish.
Hoboken[25]	400				Bored in 1828; rock at 40 feet.
Jersey City (Limbeck's brewery).[26]	776½	8	33		
Jersey City (Malone & Co.).	500		50		
Jersey City (stock yards)[27]	455	8-6½			
Jersey City (Communipaw).	500				Salt water.
Jersey City (sugar refinery).[26]	1,000	8-4	50		
Jersey City (Cox's brewery).[26]	400	5	Few.		
Jersey City (Dixon Co.)	1,205		22		
Jersey City (Colgate & Co.).	1,500		15		Rock 35 to 1,500 feet.
Jersey City (Hudson Canal Co.).	650		Few.		
Jersey City (Traction Co.)	2,200				No water.

[1] Record, N. J. Geol. Surv. Rept., 1893, pp. 413–414.
[2] Ibid., 1900, pp. 144–147.
[3] Ibid., 1885, p. 135; 1891, pp. 230–231
[4] Ibid., 1902, pp. 70–72.
[5] Ibid., 1898, pp. 78–82.
[6] Ibid., 1902, pp. 84–93.
[7] Ibid., 1900, pp. 129–131.
[8] Ibid., 1893, pp. 398–399.
[9] Ibid., 1896, pp. 171–173.
[10] Ibid., 1892, pp. 279–281.
[11] Ibid., 1902, p. 94.
[12] Ibid., 1890, p. 268.
[13] Ibid., 1896, pp. 175–177; *1896, p. 211; 1899, p. 109.*
[14] Ibid., *1897, pp. 247–248.*
[15] N. J. Geol. Surv. Rept., 1903, p. 86.
[16] Record, ibid., 1885, p. 131; 1894, pp. 190–193.
[17] Ibid., 1901, pp. 64–65; 1902, p. 80.
[18] Ibid., 1897, pp. 227–229.
[19] Ibid., 1884, p. 127; 1885, p. 133.
[20] Ibid., 1879, p. 126; 1882, p. 142; 1885, p. 115.
[21] Ibid., 1879, p. 126; 1882, p. 142; 1885, p. 114.
[22] Ibid., 1894, pp. 407–409.
[23] Ibid., 1896, pp. 126–127.
[24] Ibid., 1901, pp. 85–86.
[25] Ibid., 1879, p. 132; 1882, p. 139; 1885, p. 111.
[26] Ibid., 1879, pp. 130–132; 1882, pp. 138–140; 1885, p. 118.
[27] Ibid., 1880, p. 172; 1882, p. 139; 1885, p. 111.

NEW JERSEY—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Hudson County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Jersey City (Mehl & Co.)[1]	1,007	.....	150	.....	
Jersey City (coal dock)[2]	450	.....	.....	.....	Brackish water.
Jersey City (John Mehl & Co.).	1,020	8	125	−110	Soft water; temp of flow, 54°.
Secaucus[3]	600	6	8	No flow.	Water from 260 to :
Hunterdon County:					
Flemington	405	.....	107	−161	
Mercer County:					
Hightstown[4]	428–500	.....	Many.	.....	
Middlesex County:					
Jamesburg[5]	481	8–6	52	.....	
New Brunswick[6]	455	1¼	.....	10	Very bad water.
Do.[7]	480	.....	Few.	.....	Very hard water.
Do.	976	8	7	.....	Water at 300 to 350
Perth Amboy (Eaglewood).	470	.....	.....	.....	No water; granite o 70 to 470 feet.
Sayreville[8]	976	8	7	.....	Some water at 300
Monmouth County:					
Allenhurst[9]	530	.....	.....	Flows.	
Do.	545	.....	.....	Flows.	
Asbury Park[10]	448	8	65¼	Flows.	Good water; temp.
Do.	800	.....	.....	Flows.	
Do.	1,130-1,045	6	.....	Flow.	2 wells.
Do.[11]	1,330	.....	.....	Flows.	
Atlantic Highlands	480	4¼	250	Flows.	
Do.	450	4¼	20	Flows.	Pumps 125 gallons ute.
Avon Inn[12]	430	3	52	Flows.	
Belmar[13]	445–480	.....	.....	Flow.	4 wells.
Do.	640–660	.....	.....	Flow.	2 wells.
Deal Beach	500–525	6	.....	Flow.	Do.
Farmingdale[14]	730	.....	.....	.....	Water from 530 fee
Hazlet[15]	577	8–4¼	.....	.....	
Holmdel[16]	601	8–4	.....	Flows.	
Key East[17]	430	3	52	.....	
Lake Como[18]	535	.....	.....	Flows.	
North Spring Lake	705	6	100	Flows.	
Oakhurst[19]	497	.....	150	− 12	
Ocean Beach[20]	485	3	25	: 34	
Do.[21]	480	3	50	Flows.	
Ocean Grove[21]	420	6	40	Flows.	
Do.[22]	1,134	.....	.....	Flows.	
Poplar	520	.....	.....	− 30	
Seabright[23]	715	6–4¼	.....	5	Water 260 to 300, 3: 685 to 715 feet.
Seagirt[24]	755	3	50	Flows.	Temp., 65°; water 570 and 694 feet.
Do.[25]	750	6	28	Flows.	
Spring Lake	465–730	.....	.....	Flows.	
Do.	710	.....	.....	.....	
Telegraph Hill[26]	575	.....	.....	.....	
West Asbury Park[27]	508–558	.....	150 each.	.....	4 wells.
Morris County:					
Morristown (2 miles west).	438	6	2¼	60	
Ocean County:					
Bayhead	710	.....	.....	Flows.	
Do.[28]	870	6–4¼	100	Flows.	
Do.	885	.....	.....	Flows.	
Bayhead (1 mile north)[29]	813	4¼–3	85	Flows.	
Barnegat Park[30]	670	.....	.....	Flows	
Beach Haven[31]	430	3	10	Flows	
Do.[29]	575	8	125	Flows.	
Berkeley Arms[32]	475	.....	60	To surface.	

[1] Record, N. J. Geol. Surv. Rept., 1898, p. 140.
[2] Ibid., 1888, p. 77.
[3] Ibid., 1879, p. 129. 1880, p. 172.
[4] Ibid., 1891, pp. 200-201.
[5] Ibid., 1880, p. 165
[6] Ibid., 1879, p. 133, 1882, p. 147; 1885, p. 113.
[7] Ibid., 1887, p. 27.
[8] Ibid., 1887, p. 27; 1888, p. 77.
[9] Ibid., 1893, pp. 413-414.
[10] Ibid., 1883, p. 20; 1884, p. 124; 1885, p. 129.
[11] Ibid., 1895, pp. 72-74.
[12] Ibid., 1885, p. 130.
[13] Ibid., 1896, p. 154.
[14] Ibid., 1898, pp. 98-100.
[15] Ibid., 1897, pp. 247-248.
[16] Ibid., 1895, pp. 147-148.
[17] Ibid., 1902, p. 68.
[18] Ibid., 1894, p. 75.
[19] Ibid., 1903, pp. 92-93.
[20] Am. Jour. Sci., 3d ser. vol. 30, p. 162.
[21] Record, N. J. Geol. Surv. Rept., 1884 1885, pp. 129-131
[22] Ibid., 1894, pp. 74-75.
[23] Ibid., 1899, pp. 76-77.
[24] Ibid. 1895, pp. 75-76.
[25] Ibid., 1902, p. 67.
[26] Ibid., 1896, p. 153.
[27] Ibid., 1899, pp. 74-76.
[28] Ibid., 1902, p. 66.
[29] Ibid., 1893, pp. 394-396, 1896, p. 152.
[30] Ibid., 1896, p. 154.
[31] Ibid., 1890, p. 266; 1893, pp. 394-396.
[32] Ibid., 1884, p. 127, 1885, p. 133.

NEW JERSEY—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Ocean County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Harvey Cedars	500	4	100	Flows.	
Do.[1]	500	4¼	120	+ 6	
Island Heights[2]	1,145	10–4¼		+ 3	Water from 368 feet.
Lakewood[3]	475		3¼	+ 17	
Do.[4]	600–625	6	100	+200	Several wells.
Mantoloking	790		25	+ 33	
Do.[5]	922		60	+ 42	
Point Pleasant[6]	806		45	Flows.	
Seaside Park[7]	515		16	Flows.	Temp., 58°.
South Beach Haven[8]	425	8–6	10	+ 14	
Toms River[9]	745				
Passaic County:					
Passaic	402	8	240	− 28	
Do.	558	8	112	− 28	Water at 400 feet.
Do.	1,000		Few.		
Paterson[10]	2,100	8–4	100		Water at 900 feet only.
Do.	900		100		
Salem County:					
Daretown[11]	405			−100	
Woodstown	776				
Somerset County:					
Bernardsville	621		8		In granite.
Union County:					
Kearney	600		50		
Plainfield	400		300		In red shale.
Union	500			Flow.	10 wells.
Waverly	450		Few.		

[1] Record, N. J. Geol. Surv. Rept., 1896, pp. 166–168.
[2] Ibid., 1901, pp. 66–68.
[3] Ibid., 1885, p. 131; 1884, p. 125; 1895, pp. 148–149; 1900, pp. 148–150.
[4] Ibid., 1898, pp. 96–98; 1899, pp. 73–74.
[5] Ibid., 1895, p. 77.
[6] Ibid., 1895, pp. 76–77.
[7] Ibid., 1898, pp. 101–102.
[8] Ibid., 1896, pp. 175–177; 1886, p. 211; 1899, p. 109.
[9] Ibid., 1893, pp. 399–400; 1894, pp. 159–180; 1898, pp. 102–103.
[10] Ibid., 1879, p. 128; 1882, p. 143; 1885, pp. 115, 117.
[11] Ibid., 1897, pp. 250–253.

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New Jersey Geological Survey, Reports of the State Geologist for 1868, 1879, 1882 to 1885, 1887 to 1889, 1890, 1892 to 1899, 1900, 1901–2, 1903.

Artesian well prospects in the Atlantic Coastal Plain region, by N. H. Darton: United States Geological Survey Bulletin No. 138, pp. 39–115, plates, Washington, 1896.

NEW MEXICO.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Chavez County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Dexter (2 miles northwest).	900	6¼	804 848	Flows.	
Dexter (1 mile north)	1,000	7		Flows.	Several water horizons; water sulphuretic.
Dexter (1 mile northeast).	400	6¼	−350	Flows.	
Dexter (1 mile south)	900	6¼	510	Flows.	Principal water-bearing horizons at 324 feet and 690 feet.
Dexter (2 miles northeast).	440	6¼ and 5¼		Flow.	2 wells; several water horizons.
Dexter	400	7	+500	Flow.	Do.
Dexter (5 miles east)	664		25	Flows.	
Dexter (6 miles east)	620				
Dexter (4 miles east)	505	5	310	Flows.	
Dexter (4 miles northeast).	454			Flows.	
Hagerman	600				
Hagerman (town well)	− 525	7¼			In progress.
Hagerman (4 miles southwest).	1,004		1,500	Flows.	
Hagerman (2½ miles northwest).		5¼			
Orchard Park (1 mile southeast).	840	6¼	987	Flows.	Water sulphuretic.
Roswell (1 mile east)	405	5	600	Flows.	

NEW MEXICO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Chavez County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Roswell	440	4	40	Flows.	
Roswell (5 miles south)	917	6¾	+324	Flows.	
Roswell (4 miles east)	560	6¾	756	Flows.	
South Spring (3 miles northeast).	.....	8¾	.....	.....	In progress.
South Spring (6 miles northeast).	400	4¾	.....	Flows.	Small flow at 190 feet; large flow at 375 feet.
South Spring (10 miles northeast).	525	7¾	+517	Flows.	
Colfax County:					
Raton	1,878	6	Few.	−300	2 wells; abandoned.
Do	1,872	6	.....	−300	
Do	+2,600	.....	.....	.....	Oil at various levels; Raton Oil and Gas Co.'s well.
Donna Ana County:					
Lenark	950	10–3	Several.	.....	Water at 382 feet.
Eddy County:					
Artesia	+835	.....	.....	.....	Not completed.
Do	580	.....	.....	.....	Drill twisted off in well.
Do	823	.....	.....	.....	In progress.
Do	830	.....	.....	.....	
Do	864	4¾	.....	.....	
Do	893	4¾	.....	.....	
Artesia (2¼ miles southeast).	872	.....	562	Flows.	Several water horizons.
Artesia (7 miles northeast).	850	6	.....	Flows.	95 pounds pressure to square inch.
Artesia (2½ miles southwest).	747	6¾	+1,725	Flows.	Several water horizons.
Artesia (1 mile southeast).	760	6	1,168	+ 2¾	Do.
Artesia (2 miles west)	450	6¾	.....	.....	In progress.
Artesia (6 miles south)	826	6	.....	Flows.	
Artesia (6 miles southwest).	813¼	6	320	Flows.	Several water horizons.
Artesia (10 miles southwest).	+500	6	.....	Flows.	
Eddy[1]	+600	.....	.....	No flow.	
Lake Arthur	+515	.....	.....	.....	In progress.
Grant County:					
Deming	980	6	Many.	−18	Never used.
Leonard Wood County:					
Pastura	857	12	70	−603	
Lincoln County:					
Carizozo	895	12–7¾	50	−90	
Galinas	414	10	70	−360	
Oscura	489	10–7¼	67	−128	
McKinley County:					
Gallup	600	10	Several.	−225	No water below 135 feet
Guam	600	10	.....	.....	
Manuelito	610	10	Few.	.....	Unsatisfactory water.
San Miguel County:					
Chapelle	960	13–8	25	−310	Water-bearing beds at 120 and 380 feet.
Las Vegas	1,860	6	Several.	−30	Strongly mineral water; abandoned.
Santa Fe County:					
Santa Fe	1,115	.....	.....	.....	
Taos County:					
Servilletta[2]	650	6	.....	.....	Dry hole.
Union County:					
Clayton	750	.....	.....	.....	Good water supply.
Mount Dora	738	.....	.....	.....	Do.
Valencia County:					
Duran	1,138	13¼–8	70	300	
La Pintada Co.	+700	.....	.....	.....	

[1] Record, Fifty-second Congress, 1st sess., Senate Ex. Doc. No. 41, part 2, p. 16, Washington, 1892.

[2] Record, U. S. Dept. of Agriculture, Artesian Wells upon the Great Plains, Report of the Geological Commission, p. 35, Washington, 1882.

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Report on New Mexico, by L. G. Carpenter: Fifty-first Congress, first session, Senate Ex. Doc., No. 222, pp. 233–241, Washington, 1890.

Report of P. H. Van Diest, on the geological conditions of artesian basins in eastern Colorado and New Mexico: Fifty-first Congress, first session, Senate Ex. Doc., No. 222, pp. 233–241, Washington, 1890.

currence of artesian and other underground waters in Texas, eastern , and Indian Territory west of the ninety-seventh meridian, by Robert :y-second Congress, first session, Senate Ex. Doc., No. 41, part 3, pp. ıington, 1892.

irrigation, etc., by R. J. Hinton: Fifty-second Congress, first session, ɔc. No. 41, part 1, pp. 5–459, Washington, 1892.

NEW YORK.

ion.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
.....	.....	.....	.....	.....	City wells.
l brewery....	700	.....	.....	.....	
le[1].....	3,012	.....	.....	.....	Gas at 497 feet only.
½ miles[2]	2,200	.....	.....	.....	For gas; unsuccessful.
:y:					
ɔil and gas	680–1,419	.....	.....	.....	Several wells.
ır)[4].....	900–2,000	.....	.....	.....	Several wells; oil or gas.
ear)[5].....	1,300–2,800	.....	.....	.....	Do.
.....	800	.....	.....	.....	Some gas.
[6].....	1,800	.....	.....	.....	Some gas at 700–800 feet.
Friendship).[5]	1,400	.....	.....	.....	4 test wells; all had show of gas but not paying.
.....	1,300	6¼	Many.	+20	
and Belvi- ween).[5]	1,600	.....	.....	.....	Some oil; other deep wells near this one.
.....	3,326	.....	.....	.....	
n (near)[4]....	3,030	.....	.....	.....	Pocket of gas, soon exhausted, at 900 feet.
n[6]	1,203 2,000	.....	.....	.....	Some oil at 1,073 feet.
.....	1,293	.....	.....	.....	Initial production of 25 barrels of oil a day.
.....	1,177	.....	.....	.....	
.....	400	.....	.....	.....	8 wells; some oil.
(4½ miles :).[10]	1,777	.....	.....	.....	
vicinity of)[2].	1,000–1,347	.....	.....	.....	Several wells.
.....	839–1,800	.....	.....	.....	Important oil well field.
:					
.er	537	10	.....	.....	
ıgh:					
ıd[12]	720	6	50	Flows.	
.....	715	6	.....	Flows.	
.....	740	.....	103	Flows.	Do.
netery[14].....	582	.....	70	.....	Soft water.
onald farm).	1,802	8–6¼	.....	.....	Gas at 500 to 580 and 1,110 feet; oil at 710 and 1,060.
and 40th sts.	1,503	8–6	.....	.....	Salt water.
; street, Ar- others.	800	.....	.....	.....	No water below 97 feet.
.....	2,148	.....	.....	.....	No water below 93 feet.
West streets..	610	8	.....	.....	Brackish water.
:					
ı[15].....	3,117	.....	.....	.....	
ı (north of) .	2,000	.....	.....	.....	
.....	500	5	.....	−50	
k	1,516	8	Several.	+ 6	
oint (near)..	1,120	.....	.....	.....	Salt well
ınty:					
near).....	1,500	.....	.....	.....	
[16].....	2,160	.....	.....	.....	
.....	500	.....	.....	.....	Abandoned.
.....	1,700	.....	.....	.....	Salt well.
.....	860	.....	.....	.....	"Frank" well.
.....	.....	.....	.....	.....	Several wells, with strong gas pressure.

analysis, Am. Inst. Mining Eng. pp. 951–952.
ıning Eng. Trans., vol. 16, pp. 953–

Y. State Museum Rept., 1899, pp.

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8–109.
0–111.

[10] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, part 2, pp. 774–775.
[11] Record, etc., Am. Inst. Mining Eng. Trans., vol. 16, pp. 930–934.
[12] Record, N. J. Geol. Surv. Rept., 1896, pp. 155–156.
[13] Ibid., pp. 156–157.
[14] Record, U. S. Geol. Surv. Bull. 138, p. 34.
[15] Record, Geol. Soc. Am. Bull., vol. 4, pp. 93–94.
[16] N. Y. State Museum Rept., 1899, pp. r115–117.
[17] Record, Rept. Supt. Onondaga Salt Springs, 1888, pl. 2.

NEW YORK—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Cattaraugus County—Cont'd.					
Hinsdale (near)[1]	+1,200				Unsuccessful.
Limestone[2]	1,500	4¼			For gas or oil.
Olean[3]	734–1,417				Several wells.
Do.[4]	1,050				Small amount of oil.
Do.[4]	1,230				Gas well.
Otto[5]	2,750				
Rock City (near)[6]	1,471–1,546				Oil wells.
Versailles[1]	1,383 1,543				For gas; unsatisfactory.
Cayuga County:					
Auburn[7]	3,570				Gas well.
Do.	3,400				
Aurora[2]	1,068				Salty water.
Chautauqua County:					
Charlotte Center[8]	2,332				For oil; unsuccessful.
Do.[9]	2,262				Do.
Clymer (4 miles east)[10]	1,975				Gas well.
Fredonia[11]	1,207				Much salty water; several gas wells in vicinity.
Jamestown[12]	1,807				For oil; unsuccessful.
Mayville[13]	1,200–1,800				Several wells; oil or gas.
Chemung County:					
Breesport	1,875	5		− 14	
Chenango County:					
Norwich	900				Small amounts of gas.
Do.[14]	2,334				Do.
Columbia County:					
Burden	900				
Hudson	500	6	40	+ 2	
Do.	696	6	40	−110	
Do.	602	6	1	− 60	
Do.	500	6	35	+ ¼	
Delaware County:					
Sidney Center	416				
Dutchess County:					
Barrytown	620	6	3	− 60	
Fishkill-on-the-Hudson	3,100	10	10	−125	
Poughkeepsie	940	6	50	+ 50	
Tivoli	425	6	2	− 30	
Erie County:					
Alden[15]	1,308				Gas well.
Buffalo	490	6			Do.
Do.[16]	1,305	5¾			Do.
Do.	560				Do.
Collins[17]	1,150				Gas at 1,106 feet.
Collins (1¼ miles northeast).[18]	1,548				Gas well.
Depew	1,685–1,700				4 wells; small supply of gas.
East Aurora[19]	1,405 1,503				Salt wells.
East Aurora and Orchard Park (between).[20]	1,000–3,000				For gas; unsuccessful.
Eden Valley[19]	1,750				Salt well.
Gardenville[21]	800				Do.
McMillan well[22]	1,720				
New Oregon[23]	2,100				Unsuccessful.
North Collins[24]	1,250				Do.
Port Colborne[25]	770–1,500				Several small gas wells.
Springville[26]					2 gas wells.
Do.	2,300				Unsuccessful.
Williamsville	(Av.) 875	5¾		No flow.	3 wells; 2 unsuccessful.

[1] N. Y. State Museum Rept., 1899, p. r118.
[2] Record, Pa. 2d Geol. Surv. Rept., Vol. II, p. 272.
[3] N. Y. State Museum Rept., 1899, pp. r118–119.
[4] Am. Inst. Mining Eng. Trans., vol. 16, pp. 939–940.
[5] N. Y. State Museum Rept., 1899, pp. r115–117.
[6] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], p. 100.
[7] Record, Am. Geol., vol. 25, pp. 156–160.
[8] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 325.
[9] Ibid., pp. 325–326.
[10] Ibid., p. 228.
[11] Analysis, Am. Inst. Mining Eng. Trans., vol. 16, pp. 918–923.
[12] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], p. 126.
[13] Record, N. Y. State Museum Rept., 1899, p. r120.
[14] Record, Geol. Soc. Am. Bull., vol. 4, p. 95.
[15] N. Y. State Museum Rept., 1899, p. r121.
[16] Record, Am. Inst. Mining Eng. Trans., vol. 16, pp. 924–925.
[17] Record, N. Y. State Museum Rept., 1899, p. r122.
[18] Ibid., p. r123.
[19] Record, Rept. Supt. Onondaga Salt Springs, 1888, pl. 2; 1885, p. 15.
[20] N. Y. State Museum Rept., 1899, p. r121.
[21] Record, Rept. Supt. Onondaga Salt Springs, 1888, pl. 2.
[22] Record, N. Y. State Museum Rept., 1899, p. r117.
[23] N. Y. State Museum Rept., 1899, p. r116.
[24] Ibid., p. r123.
[25] Record, Am. Inst. Mining Eng. Trans., vol. 17, p. 401.
[26] N. Y. State Museum Rept., 1899, p. r122.

NEW YORK—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Genesee County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Alexander					Salt well.
Batavia					
Corfu (2 miles west)	1,208 1,248	8–6¼		−15 and −135	Several gas wells.
Darien[1]	+1,300				
Leroy[2]	878–1,003				Salt wells.
Greene County:					
Cairo (3½ miles southwest).[3]	2,200	5½		−310	For oil or gas; abandone
Herkimer County:					
Ilion[4]	1,135				Gas in small quantities 800, 950, and 1,000 feet.
Mohawk	420	6		− 30	Sulphurous water.
Jefferson County:					
Watertown[5]	530				Some gas at 253 feet.
Lewis County:					
Greig	700				Bored for oil.
Livingston County:					
Caledonia	1,100	8–6¼		− 25	Salty, sulphurous wate
Do.[6]	760				Salt well.
Cuylerville[6]	1,145				Do.
Dansville	1,800				
Dansville (near)[7]	+508				Gas at 295 and 508 feet.
Do	2,240				No gas reported.
Greigsville[8]	1,138–1,145				Salt wells.
Do.[1]	1,800				For gas; unsuccessfu black sulphur water 1,315 feet.
Lakeville[4]	1,053				Salt well.
Leicester	1,165				Do.
Livonia[9]	1,432	Shaft.			Salt mine.
Do	1,100				Salt well.
Mount Morris[8]	1,130–1,422				Several salt wells.
Nunda[8]					Do.
Piffard[10]	961–1,141				
York[8]	828				Salt well.
Madison County:					
Canastota	648				Bitter brines.
Chittenango[11]	3,026				Gas well.
Eagleville	1,889				
Eaton	400	5	20	− 3	
Morrisville[12]	1,889				Do.
Uniontown					Do.
Manhattan Borough:					
Governors Island	1,822	12–6	18	Flows.	Flow of 15 gallons at 1,7 feet was increased torpedoing; salty.
Tenth and Washington streets.	500	6	600	No flow.	
Fifth Avenue Hotel	1,108				No water.
Greenwich and 11th streets.	1,047	8	10	No flow.	
United States Hotel	629 (or 900)		Several.		
Twenty-eighth st., near Broadway.	500	8	100	No flow.	
Avenue D, foot of East Tenth street.	1,194		Several.		
Fourth avenue and 47th street.	600	8	100	No flow.	
Foot of 47th st.	402				
Eleventh avenue and 59th street.	700	8	100	No flow.	
Fourth avenue and 51st street.	1,194		Few.		
Eighth avenue and 72d street.	1,200	8	8	No flow.	
Fifth avenue and 59th street.	500		80	No flow.	
Third avenue and 92d street.	685	9	300	No flow.	
Eighth avenue and 145th street.	605	10–8		No flow.	

[1] N. Y. State Museum Rept., 1899, p. r124.
[2] Record, Rept. Supt. Onondaga Salt Springs, 1888, pl. 2; 1884, pp. 19–20.
[3] Record, Am. Inst. Mining Eng. Trans., vol. 16, p. 956.
[4] Record, Am. Geol., vol. 25, pp. 132–135.
[5] Record, Geol. Soc. Am. Bull., vol. 4, p. 107.
[6] Record, Rept. Supt. Onondaga Salt Springs, 1888, pl. 2; 1885, p. 15.
[7] N. Y. State Museum Rept., 1899, p. r128.
[8] Record, Rept. Supt. Onondaga Salt Sprin 1888, pl. 2.
[9] Am. Geol., vol. 15, p. 379; N. Y. State Ge Rept., 1893, vol. 1, p. 13.
[10] Record, Rept. Supt. Onondaga Salt Sprin 1884, pp. 20–21.
[11] Record, Geol. Soc. Am. Bull., vol. 4, p. 101.
[12] Ibid., pp. 96–97; Rept. Supt. Onondaga S Springs, 1888, pl. 2.

NEW YORK—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Rensselaer County:					
Shodack Landing	1,000?				Salt well.
Richmond County:					
New Dorp	600				No water.
Hoffmans Island	1,000	8		33	Salt water to 900 feet
Saratoga County:					
Ballston	560			+60	Mineral water.
Do	778	6		− 3	
Saratoga Springs	400	6	3½		
Do	1,006	2½	2	+75	
Do	600	6	½	Flows.	
Do	440	6	½	+40	
Do	520	6	½	+40	
Do	425	6	½	−16	
Do	478?			+40	Do.
Do	422			−16	
Schuylerville	610	8	84	− 6	
Schenectady County:					
Niskayuna	400	6	75	−20	
Schuyler County:					
Glen Springs	1,500				For oil; unsuccessful
Watkins	2,100±				Several salt wells.
Do[1]	1,100				Abandoned.
Do[1]	800				
Do[1]	1,715				Gas, at 1,350 feet.
Seneca County:					
Seneca Falls	3,560				Gas well.
Do	400-500			Flow.	Several salt wells in ity.
Do[2]	1,500				Gas well.
Steuben County:					
Addison and Corning (between).[3]	1,148				
Bath (half mile south).	2,050				Gas well.
Bloods[4]	1,495				Showing of gas.
Campbell Township[5]	2,800				For gas; unsuccessf
Campbell[6]	2,250				For oil or gas.
Canisteo	2,000				Several unsuccessfu
Canisteo (and vicinity)[7]	735-1,300				Several gas wells.
Corning[5]	3,000				Salt water prevente ther drilling.
Cohocton (near)					For oil.
Howard (one-half mile west).	2,000				For oil or gas; unsu ful.
Hornby Township (near south line).[5]	1,528				Gas well.
Hornellsville[4]	2,200				Good veins of gas 1,250, and 1,560 fe
Do	1,500	6¼			Gas at 650, 940, and feet, 3 wells of depth.
Do	1,522	6¼			Gas well.
Lavona[8]	3,005				2 wells; little gas a in both.
Prattsburg (1¼ miles southwest).[4]	1,800				
Do.[8]	1,200				
Rexville[5]	1,635-1,181				Do.
Rheims[8]	2,000				Showing of gas.
Spring Mills (near)[5]	1,635				Small amount of ga
Troupsburg[5]	632				Gas well.
Urbana	2,000	6	8	−30	
Woodhull	3,000			−50	Unsuccessful oil we of water at 300 fe
Wyleysville[5]	2,010				Gas well.
Suffolk County.					
Cold Spring Harbor (1 mile north).	410	6	10	+ 1	
Do	400	8	75	No flow.	Water-bearing beds and 303 feet.
Fishers Island	485	6			Salt water.
Huntington (2 miles northwest).	498	3			Incomplete; no wa low 88 feet.
Greenport	690	6			Salt water 225 to 55 small flow of fresh at 665 feet, bed r 670 feet.
Orient (Long Beach Point).	+406				Salt water.

[1] N. Y. State Museum Rept., 1899, p. r127.
[2] Record, Am. Inst. Mining Eng. Trans., vol. 16, p. 949.
[3] Record, N. Y. State Museum Rept., 1899, p. r130.
[4] N. Y. State Museum Rept., 1899, p. r128.
[5] Ibid., p. r132.
[6] Record, Geol. Soc. Am. Bull., vol. 4, pp.
[7] Record, N. Y. State Museum Rept., 1899,
[8] Ibid., p. r129.

NEW YORK—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Sullivan County:					
Neversink (near)	1,400				Gas boring; abandoned.
Tioga County.					
West Candor.[1]	1,200				Barren.
Tompkins County:					
Ithaca	2,250	10-6½			Two dry salt wells.
	2,250	8-5½			
Ithaca (one-fourth mile south).[2]	3,185	8-5½			Gas well.
Ludlowville	1,821	8			Salt wells.
Wayne County:					
Alloway[3]	2,365				
Clyde	450	6		-12	
Do[4]	1,792				
Lyons (2 miles south)[5]	2,340				No gas of value.
Wolcott[6]	2,383				Gas well.
Westchester County:					
New Rochelle	1,156	10		10	
Port Chester	500 and 639				2 wells.
Do[7]	417				Satisfactory supply.
Purchase	600				
Rye	500	8			
Wyoming County:					
Attica[8]	1,960				
Bliss[9]	2,956				Gas well.
Castile[10]	2,525				Salt well.
Pearl Creek	1,182-1,194				Salt wells.
Pearl Creek (1 mile south).	1,241				Do.
Perry[11]	2,108				Heavy bed of salt.
Rock Glen[8]	2,111				Salt well.
Saltvale[8]	1,436				Do.
Silver Springs[8]	2,254				Do.
Warsaw[8]	1,609-2,039				Numerous salt wells.
Wyoming[8]	1,321-1,530				Salt well.
Yates County:					
Dundee	2,000				Rock salt at 1,800 feet.
Do	1,200				
Penn Yan[11]					Small supply of gas for several weeks.
Do.[12]	2,053				Not enough gas to utilize.
Fort Greble[13]	762				Moderate supply of water of good quality.

[1] N. Y. State Museum Rept., 1899, p. r132.
[2] Record and analysis, Am. Inst. Mining Eng. Trans., vol. 16, p. 941; Rept. Supt. Onondaga Salt Springs, 1888, pl. 2.
[3] Record, Am. Geol., vol. 25, 1900, pp. 353-355.
[4] Record, Am. Inst. Mining Eng. Trans., vol. 16, p. 942.
[5] Partial record, N. Y. State Museum Rept., 1899, p. r133
[6] Am Inst. Mining Eng. Trans., vol. 13, p. 943.
[7] N. J. Geol. Surv. Ann. Rept., 1900, p. 156.
[8] Record, Rept. Supt. Onondaga Salt Springs, 1888, pl. 2.
[9] Record, N. Y. State Museum Rept., 1899, p. r133.
[10] Record, Rept. Supt Onondaga Salt Springs, 1888, pl. 2; Rept., 1885, p. 15.
[11] Am. Inst. Mining Eng. Trans., vol. 16, pp. 939-940
[12] Partial record, N. Y. State Museum Rept., 1899, p. r134
[13] N. J. Geol. Surv. Ann. Rept., 1900, pp. 155-156.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN NEW YORK.

Annual Report of Superintendent of Onondaga Salt Springs for 1888, 26 pages, plates, Albany, 1889.

Thickness of the Devonian and Silurian rocks of central New York, by G. S. Prosser: American Geological Society Bulletin, volume 4, pages 91-118, Rochester, 1893.

United States Geological Survey Bulletin No. 138, 232 pages, Washington, 1896.

Gas well sections in the upper Mohawk Valley and central New York, by C. S. Prosser: American Geologist, volume 25, pages 131-162, March, 1900.

Petroleum and natural gas in New York State, by C. A. Ashburner: American Institute of Mining Engineers Transactions, volume 16, pages 906-953.

Section of the Alloway (New York) well, by C. S. Prosser: American Geologist, volume 25, 1900.

Fifty-third Annual Report of the New York State Museum for 1899.

NORTH CAROLINA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Durham County:					
Durham	1,037		18	No flow.	
Johnston County:					
Selma					2 deep wells.
Mecklenburg County:					
Charlotte	900	2			Dry.
Davidson	500				Dry below 80 feet.
Moore County:					
Sanford	515	6½	45	— 3	
New Hanover County:					
Hammocks	400		8		Water at 100 feet.
Wilmington	496			Flows.	Saline water.
Do.[1]	1,144	12–6	200		Flows of brackish water at 379, 496, 574, 608, 734, and 949 feet; 200-gallon flow at 518 feet; granite, 1,109 feet to bottom.
Rowan County:					
Goldhill	1,000			−20	Shaft sunk for gold.
Stokes County:					
Walnut Cove	1,050	2½			For coal; unsuccessful.
Walnut Cove (1 mile south).	500				Mineral water; good flow.
Union County:					
Monroe	720	6–5	28	To surface.	
Do	1,050	8–6	28	Near surface.	
Wilkes County:					
Northwilkesboro	600	8	85		Uncompleted.

[1] Science, new ser., vol. 11, 1900, pp. 128–130.

PUBLICATIONS RELATING TO DEEP BORINGS IN NORTH CAROLINA.

Artesian well prospects in the Atlantic Coastal Plain region, by N. H. Darton: U. S. Geological Survey Bulletin No. 138, 232 pages, plates, Washington, 1896.

Science, new series, volume 11, 1900.

NORTH DAKOTA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Barnes County:					
Ashtabula (2½ miles west of).	1,340			− 11	Principal water horizon at 1,325 feet.
Wimbleton[1]	1,557		200	+184	
Billings County:					
Medora[1]	941	4	33	+ 34½	
Burleigh County:					
Bismarck[1]	1,315	8–4			No flow.
Cass County:					
Buffalo (6 miles northeast).	514		25	+115	Staple's well.
Tower City[1]	716	6–4½	20–25	+122	
Dickey County:					
Ellendale (12 miles northeast).	1,022	1	25	Flows.	
Ellendale (15 miles northeast).	1,036	2–1	18	Flows.	
Ellendale[1]	860			+138	
Ellendale (west of)	600				No water.
Ellendale (12 miles northwest).	1,015	1			
Ellendale[1]	1,087	4½–3½	700	+260	Water at 1,042 feet.
Glover (near)		1½	37		
Do	1,000	2		+111	
Ludden (south of)	940	2			
Ludden (north of)	1,050	1½	10		
Do	980	2		+65	
Oakes[1]	977				Water at 790, 845, 870, and 937 feet.

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, pp. 59–63.

NORTH DAKOTA—Continued.

ıtion.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
y—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
st of)	1,050	2			
	960	2		+31	
	944				
miles north-	906	1¼	20	Flows.	
nty:					
	1,354	6	500	+138	Water at 1,300 and 1,350 feet.
y:					
	2,000	10–4	3		Water at 327 feet only.
	1,311				No flow.
nty:					
[2]	1,565	6	16½	+ 60	
ty:					
ke[3]	1,520	8–3	82	+ 46	Flow at 1,470 feet.
ty:					
ır)	960	1¼	4,33		2 wells.
		1¼			
(near)	980	1¼	30		
ıst of)	960	1¼	33		
		1¼			
	960	1¼	35	+184	
	650	2	64	+160	
st of)	875	1¼	35	+276	
ır)	980	1¼	30		
	600	2			
	685				
e (near)	1,075	2	30		
ear)		2	136		
ortheast of)	960	2	4		
	1,325				No flow.
nty:					
n (asylum)[2]	1,524	8–3½	4	+161	
n[1]	1,476	6¼–3½	460	+223	Water at 1,385 and 1,458 feet.
:					
	560		175	Flows.	
:					
	912	8	700		
:					
ıear)	2,125		2½	Flows.	Pressure 13 pounds.

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, pp. 59–63.
[2] 51st Cong., 1st sess., Senate Ex. Doc. No. 222, 1890, p. 322.
[3] Record, ibid., 1890, pp. 107–108.

ıL PUBLICATIONS RELATING TO DEEP BORINGS IN NORTH DAKOTA.

f F. S. Underhill for North Dakota: Fifty-first Congress, first session, Doc. No 222, pages 105–109, Washington, 1890.

ı Irrigation, Fifty-second Congress, first session, Senate Ex. Doc. No. 41, s 66–72, 87–94, Washington, 1893.

ıry report on artesian waters of a portion of the Dakotas, by N. H. nited States Geological Survey, Seventeenth Annual Report, 1895–96, s 609–694, Washington, 1896.

NORTH CAROLINA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Durham County:					
Durham	1,037		18	No flow.	
Johnston County:					
Selma					2 deep wells.
Mecklenburg County:					
Charlotte	900	2			Dry.
Davidson	500				Dry below 80 feet.
Moore County:					
Sanford	515	6¼	45	— 3	
New Hanover County:					
Hammocks	400		8		Water at 100 feet.
Wilmington	495			Flows.	Saline water.
Do.[1]	1,144	12–6	200		Flows of brackis at 379, 496, 574, and 989 feet; 2(flow at 518 feet; 1,109 feet to bot
Rowan County:					
Goldhill	1,000			—20	Shaft sunk for go
Stokes County:					
Walnut Cove	1,050	2½			For coal; unsucce
Walnut Cove (1 mile south).	500				Mineral water: g(
Union County:					
Monroe	720	6–5	28	To surface.	
Do	1,050	8–6	28	Near surface.	
Wilkes County:					
Northwilkesboro	600	8	85		Uncompleted.

[1] Science, new ser., vol. 11, 1900, pp. 128–130.

PUBLICATIONS RELATING TO DEEP BORINGS IN NORT CAROLINA.

Artesian well prospects in the Atlantic Coastal Plain region, by N. H. I U. S. Geological Survey Bulletin No. 138, 232 pages, plates, Washington, 189(Science, new series, volume 11, 1900.

NORTH DAKOTA.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Barnes County:					
Ashtabula (2½ miles west of).	1,340			— 11	Principal water h 1,325 feet.
Wimbleton[1]	1,557		200	—184	
Billings County:					
Medora[1]	941	4	33	+ 34½	
Burleigh County:					
Bismarck[1]	1,315	8–4			No flow.
Cass County:					
Buffalo (6 miles northeast).	514		25	+115	Staple's well.
Tower City[1]	716	6–4½	20–25	+122	
Dickey County:					
Ellendale (12 miles northeast).	1,022	1	25	Flows.	
Ellendale (15 miles northeast).	1,036	2–1	18	Flows.	
Ellendale[1]	860			+138	
Ellendale (west of)	600				No water.
Ellendale (12 miles northwest).	1,015	1			
Ellendale[1]	1,087	4½–3½	700	+260	Water at 1,042 fee
Glover (near)		1½	37		
Do	1,000	2		+111	
Ludden (south of)	940	2			
Ludden (north of)	1,050	1½	10		
Do	980	2		+65	
Oakes[1]	977				Water at 790, 845, 937 feet.

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 2, pp. 59–63.

OHIO—Continued.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
nty:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
lle[1]	2,700				Gas wells.
	1,550 2,700				Small gas wells.
(1 mile north-	1,680				Salt water only.
	1,707				
Ferry[4]	2,300				
	2,325				
l	1,237–1,900				Several wells.
	1,812–1,858				
ton	1,125				Gas.
ty:					
rab	800–1,200	5½			Gas wells.
					No product.
y:					
1[5]	550–700				Gas wells; small flow.
wn[6]	1,060				Some gas and salt water.
	1,365				Shale gas and sulphur water only.
e	1,220	8		6	Salt water and some gas.
ty:					
im (east of)[7]	953–1,040				4 wells.
of[7]	1,135				
nwest of[7]	1,177				
Township[8]	1,500				Dry hole.
	928				Good show of oil.
(north of)[7]	1,032				
Township[9]	1,130–1,240				4 wells; 3 produced oil.
ville (west)[8]	+900				Gas and salt water; well abandoned.
wnship[9]	1,500				Some oil.
	2,000				Large flow of salt water.
County:					
[10]	+1,000				Two unsuccessful borings.
	1,307–1,350				Very small showing of gas
:					
isle[12]	1,060				For gas; unsuccessful.
nship[12]	1,380				Do.
ld[12]	1,140–1,200				Several wells; failures.
unty:					
[3]	400				Gaswell.
burg	660	6			Small flow of gas.
	660	6			Unsuccessful.
ity:					
na[14]	1,785				Salt water at 1,785 feet.
County:					
[5]					Several gas wells.
	1,008				
(south of)[17]	1,507				Much salt water; some oil, well closed.
rpool[18]	425–450				
ry Run[19]	±3,000				Several gas wells.
les well	2,954				Dry.
stine (near)[20]	1,700				
nester[21]	+725				
rth (near)[20]	+618				Oil well.
n[22]	600				
	1,582				
l (Township)	426				Brine.
Township[24]	1,600–3,000				3 wells.
ownship[25]	1,012				Oil well.
on[26]	1,350–1,370				Gas wells.
ip unknown)	600				
	1,350–2,930				3 wells.

l. Surv. Rept., 1890, p. 254.
5, vol. 6, p. 406.
), pp. 253–254.
5, vol. 6, pp. 404–406.
bid., p. 292–293.
94–295.
l. Surv. Bull. No. 198, 1902, pp. 25–33.
Surv. Bull. No. 1, 4th ser., 1903, p. 293.
94.
bid., Rept., 1888, vol. 6, pp. 276–277.
75.
278–280.
l. Surv. Rept., 1888, vol. 6, p. 301.
296–297.
ll. No. 1, 4th ser., 1903, pp. 263–264.
[10] Record, ibid., pp. 261–262.
[17] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 258.
[18] Record, ibid., Rept., 1888, vol. 6, pp. 331–334.
[19] Ibid., pp. 322–323.
[20] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 256.
[21] Ibid., p. 257.
[22] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, part 2, pp. 784–785.
[23] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 322.
[24] Ibid., Bull. No. 1, 4th ser., 1903, p. 253.
[25] Ibid., p. 259.
[26] Record, ibid., Rept. 1888, vol. 6, p. 404.

OHIO.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Allen County[1]					Many oil and gas wells. 83 per cent producers.
Amanda Township	1,200	10–5¾		−75	Salt water at 20 feet.
Beaverdam[2]	1,345				For oil; salt water found.
Bluffton[3]	1,328				Unsuccessful.
Delphos[4]	1,250				Do.
Delphos (Kill farm)[5]	1,218				Oil well.
Lima[6]	1,200–1,400				Numerous oil wells here and in county; much salt water found.
Spencerville (near)[7]					Several wells; good flow of gas with some oil.
Westminster[8]	1,400				For oil or gas; failure.
West Newton[8]	1,440				
Ashtabula County:					
Ashtabula[9]	500				Gas 250–500 feet; strong brine at 400 and 500 feet.
Cherry Township[10]	2,775				
Conneaut[11]	850				Small gas supply.
Do	+1,942				Much strong brine.
Jefferson[10]	2,140				Some oil.
Jefferson (2 miles northwest).[10]	1,989				Considerable gas.
North Kingsville[12]	1,200				
Geneva[13]	850–1,375				2 wells; fair flow of gas; numerous other wells in the county.
Jefferson (near)[14]	1,992				Gas and oil well.
Jefferson	2,021				Gas.
Do	2,110				Dry.
South Kingsville[15]	1,200				Gas well; some oil.
Athens County:					
Athens (3 miles northeast of court-house).[16]	1,250				Some oil and gas.
Athens	±1,200				Oil and gas wells.
Athens (1½ miles west)[16]	1,050				Some gas; abandoned.
Athens (near)[16]	1,135				Salt water, oil and gas.
Do.[16]	1,144				Considerable gas; no oil.
Berne Township[17]	+1,300				2 wells; yielded much salt water and little oil; abandoned.
Canaan Township[16]	+1,244				Abandoned on account of accident in shooting.
Marshfield (1 mile northwest).[18]	2,718				
Mineral[18]	1,060				
Do.[18]	3,255				
Nelsonsonville[19]	570–950				Many salt wells; one small gas well.
Trimble Township[20]					Several gas wells.
Auglaize County[21]					Many oil and gas wells; 84 per cent producers.
Cridersville	1,227	8–5¾		−40	Oil and salt water.
Duchouquet					2 wells of moderate flow.
Logan Township[22]					Oil well; started with production of 250 barrels a day; other wells near gave equal or better results.
St. Marys[23]	1,230				Salt water only.
Do.[23]	1,132–1,225				Several oil wells.
Do.[23]	1,092–1,138				Several gas wells; large flows.
Uniopolis					Very small flow of gas; abandoned.
Wapakoneta[24]	1,600				For oil or gas; salt water only.

[1] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 78–85.
[2] Ibid., p. 79. Abandoned at 1,309 feet in 1886; new casing inserted in 1899, and pumping caused well to produce 25 barrels of oil per day, but this rapidly decreased to a very small amount. Other productive wells near.
[3] Ibid., Rept. 1888, vol. 6, p. 216.
[4] Record, ibid., p. 240.
[5] Ibid., 1890, p. 217.
[6] Ibid., 1888, vol. 6, pp. 165–168.
[7] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 82.
[8] Record, ibid., Rept. 1888, vol. 6, p. 220.
[9] Ibid., pp. 424–425.
[10] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 303.
[11] Ibid., Rept. 1888, vol. 6, pp. 422–423.
[12] Ibid., Bull. No. 1, 4th ser., p. 302.
[13] Record, ibid., Rept. 1888, vol. 6, pp. 425–426.
[14] Ibid., Bull. No. 1, 4th ser., 1903, p. 21.
[15] Ibid., Rept. 1888, vol. 6, pp. 423–424.
[16] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 269–270.
[17] Ibid., p. 139.
[18] Ibid., pp. 271–272.
[19] Ibid., Rept. 1888, vol. 6, p. 398.
[20] Ibid., Bull. No. 1, 4th ser., 1903, p. 263.
[21] Ibid., pp. 85–89.
[22] Ibid., p. 85.
[23] Ibid., Rept. 1888, vol. 6, pp. 255–258.
[24] Ibid., p. 254.

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
elmont County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Barnesville[1]	2,700				Gas wells.
Bellaire[2]	1,550 2,700				Small gas wells.
Flushing (1 mile northeast).[3]	1,680				Salt water only.
Goshen	1,707				
Martins Ferry[4]	2,300				
Mead	2,325				
Richland	1,237–1,900				Several wells.
Warren	1,812–1,858				
Washington	1,125				Gas.
Brown County:					
Mount Orab	800–1,200	5¼			Gas wells.
Ripley					No product.
Butler County:					
Hamilton[5]	550–700				Gas wells; small flow.
Middletown[6]	1,060				Some gas and salt water.
Oxford[6]	1,365				Shale gas and sulphur water only.
Sevenmile	1,220	8		6	Salt water and some gas.
Carroll County:					
Amsterdam (east of)[7]	953–1,040				4 wells.
West of[7]	1,135				
Northwest of[7]	1,177				
Augusta Township[8]	1,500				Dry hole.
Do	928				Good show of oil.
Germano (north of)[7]	1,032				
London Township[9]	1,130–1,240				4 wells; 3 produced oil.
Sherrodsville (west)[8]	+900				Gas and salt water; well abandoned.
Union Township[9]	1,500				Some oil.
Do	2,000				Large flow of salt water.
Champaign County:					
St. Paris[10]	+1,000				Two unsuccessful borings.
Urbana[11]	1,307–1,350				Very small showing of gas
Clark County:					
New Carlisle[12]	1,060				For gas; unsuccessful.
Pike Township[12]	1,380				Do.
Springfield[12]	1,140–1,200				Several wells; failures.
Clermont County:					
Felicity[13]	400				Gaswell.
Williamsburg	660	6			Small flow of gas.
Do	660	6			Unsuccessful.
Clinton County:					
Sabina					
New Vienna[14]	1,785				Salt water at 1,785 feet.
Columbiana County:					
Corning[15]					Several gas wells.
Do.[16]	1,008				
Corning (south of)[17]	1,507				Much salt water; some oil, well closed.
East Liverpool[18]	425–450				
On Dry Run[19]	±3,000				Several gas wells.
Knowles well	2,954				Dry.
East Palestine (near)[20]	1,700				
East Rochester[21]	+725				
Homeworth (near)[20]	+618				Oil well.
Island Run[22]	600				
Lisbon[23]	1,582				
Liverpool (Township)	426				Brine.
Madison Township[24]	1,600–3,000				3 wells.
Monroe Township[25]	1,012				Oil well.
New Lisbon[26]	1,350–1,370				Gas wells.
(Township unknown)	600				
Do	1,350–2,930				3 wells.

[1] Ohio Geol. Surv. Rept., 1890, p. 254.
[2] Ibid., 1888, vol. 6, p. 406.
[3] Ibid., 1890, pp. 253–254.
[4] Ibid., 1888, vol. 6, pp. 404–406.
[5] Record, ibid., p. 292–293.
[6] Ibid., p. 294–295.
[7] U. S. Geol. Surv. Bull. No. 198, 1902, pp. 25–33.
[8] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 293.
[9] Ibid., p. 294.
[10] Record, ibid., Rept., 1888, vol. 6, pp. 276–277.
[11] Ibid., p. 275.
[12] Ibid., pp. 278–280.
[13] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 301.
[14] Ibid., pp. 296–297.
[15] Ibid., Bull. No. 1, 4th ser., 1903, pp. 263–264.
[16] Record, ibid., pp. 261–262.
[17] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 258.
[18] Record, ibid., Rept., 1888, vol. 6, pp. 331–334.
[19] Ibid., pp. 322–323.
[20] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 256.
[21] Ibid., p. 257.
[22] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, part 2, pp. 784–785.
[23] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 322.
[24] Ibid., Bull. No. 1, 4th ser., 1903, p. 253.
[25] Ibid., p. 259.
[26] Record, ibid., Rept. 1888, vol. 6, p. 404.

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Columbiana County—Con.					
Salem [1]	+800–810				Two unsuccessful borings.
Do	2,980				Unproductive.
Salineville [2]	3,200				Failure.
Wellsville (near) [3]	2,600				Gas well.
Do. [4]	3,250				Failure.
Do. [4]					Oil wells.
Coshocton County:					
Adams Township [5]	600–1,800				3 wells.
Coshocton [6]	2,108				
Do. [7]	1,280				Unsuccessful.
Do. [8]	3,100				Do.
Lafayette Township [5]					5 wells.
Crawford County:					
Bucyrus [9]	840–2,264				For gas or oil; salt-water flow at 750 feet.
Cuyahoga County:					
Berea (2½ miles northeast). [10]	960–1,240				Several gas wells.
Brooklyn village [11]	1,083				Several gas wells near.
Cleveland [11]	400–1,500				Several gas wells.
Gas company [11]	2,200				No product.
Euclid and Case avenues. [12]	1,125–1,735				Small flow of gas.
Rolling Mill [13]	3,000				
Central avenue	535		Many.	−100	Large supply of water.
Gordon Park [14]	520				Abandoned.
2 miles east [15]	508				For oil and coal; failure.
Independence [16]	1,800				Several borings for oil; no product.
Newburg [13]	3,000	5½			Some gas; much salt water.
Rockport [17]	527–1,385				2 gas wells; small flows.
Darke County:					
Arcanum [18]	+1,150				Gas prospects; small product.
Greenville [19]	1,200–1,700				Several borings for gas; unsuccessful.
Defiance County:					
Defiance	1,687				Salt water only.
Hicksville [20]	1,710				Salt water; some oil.
Delaware County:					
Delaware [21]	2,130				Unsuccessful.
Sunbury [22]	2,530				
Erie County:					
Birmingham [23]	2,250				Salt water only.
Milan [24]	2,000				For oil or gas; only salt water found.
Sandusky [25]	2,260				Some oil, gas, and salt water.
Fairfield County:					
Berne Township [26]	2,236				
Carroll [27]	2,300				Unsuccessful.
Lancaster [28]	1,030				
Do. [29]	1,940–2,020	4½–5½			Several gas wells.
Lancaster (4 miles below). [30]	2,088				
Sugar Grove (near) [31]	+2,236				For oil or gas.
Do. [31]	2,075				Do.
Thurston [32]					2 gas wells.

[1] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 403–404, 452.
[2] Ibid., Bull. No. 1, 4th ser., 1903, p. 257.
[3] Ibid., p. 22.
[4] Ibid., pp. 251–252.
[5] Ibid., p. 292.
[6] Record, ibid., Rept., 1885, vol. 6, p. 324.
[7] Ibid., p. 368.
[8] Ibid., p. 357, 1890 pp. 245–246.
[9] Ibid., pp. 363–364.
[10] Ibid., pp. 433–436.
[11] Ibid., pp. 429–431.
[12] Geol. Soc. Am. Bull., vol. 8, p. 10.
[13] Record, Mich. Geol. Surv. Rept., 1881–1893, vol. 5, part 2, p. 73. Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 351–355.
[14] Geol. Soc. Am., Bull., vol. 8, p. 10.
[15] Economic Geol., Ill., vol. 3, pp. 195–196.
[16] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 431.
[17] Record, ibid., pp. 432–434.
[18] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 272–273.
[19] Ibid., pp. 271–272.
[20] Record, ibid., pp. 250–251.
[21] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 270.
[22] Ibid., p. 283.
[23] Ibid., pp. 346–347.
[24] Ibid., p. 346.
[25] Record, Mich. Geol. Surv. Rept., 1881–1893, p. 83. Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 194–196.
[26] Partial record, Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 118.
[27] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 388.
[28] Record, ibid., p. 318.
[29] Ibid., pp. 382–388, 783.
[30] Ibid., Bull. No. 1, 4th ser., 1903, pp. 117–118.
[31] Partial record, ibid., pp. 20–21.
[32] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 107–108.

OHIO—Continued.

ɔcation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
ınty:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
gton[1]	1,850				For gas or oil; found salt water only.
ɔunty:					
ıus[2]	2,020				No gas or oil.
ıus (State House)[3]	2,775	6–4		+5	Saline water below 175 feet; temp., 91°.
ɔrt (near)[4]	2,675				
urg[5]	405	6	Many.	Flows.	
ille[6]	+2,300				
ıty:					
	2,150				Unsuccessful.
n[8]	+2,158				Oil at 2,158 feet.
ty:					
·ille	800				Considerable gas at 400 feet.
is[9]	2,910				For oil; unsuccessful.
gton Township[10]	1,765				Failure.
ı Township[11]	1,417				Much salt water; failure.
ip unknown	2,910				Dry well.
ınty:					
ɜn (near)[12]	2,472				Only a showing of oil.
Township[13]	1,500				Some gas; well considered a failure.
nty:					
wn	1,500				Salt water only.
	990				Unsuccessful.
'alley[14]	1,500				Do.
	1,200				For oil or gas; unsuccessful.
ɔunty:					
ıge[16]	1,090–2,000				Gas and oil wells; yield small.
Township)	690				Brine.
ton[17]	1,087				Unsuccessful.
					Some gas.
station[18]	430				Salt well.
City[19]	1,347				Gas well.
	1,352				
					A number of oil and gas wells reported.
ounty:					
ati (vicinity)					Numerous oil or gas wells; unsuccessful.
ati	2,400 1,200				2 wells.
end	1,350	5	200	+30	Good water.
ɔunty:[21]					Many oil wells; 84 per cent producers.
[22]	1,365				Gas at 1,180 feet.
(near)[23]	+1,200				
ɔn[22]	1,304				Some oil and gas at 1,304 feet; abandoned.
lam (5 miles [24]	1,288–1,290				Gas wells.
sburg[25]	1,300				Several oil wells.
wnship[23]	+1,150				
[26]	1,116–1,334				Many gas wells; some oil in several wells.
[7]	1,648				Gas well; oil at 1,092 feet; salt water at 1,581 feet.
(1 mile north- [28]	1,334				Unsuccessful.

Ohio Geol. Surv. Rept., 1888, vol. 6, p.

ɔ. 281–283.
ɔ. 106–108; Am. Jour. Sci., 2d ser., vol.

ıll. No. 1, 4th ser., 1903, p. 19.
ı, U. S. Geol. Surv., 19th Ann. Rept., ırt 4, p. 664.
ol. Surv. Rept., 1888, vol. 6, p. 283.
ɔ. 244–245.
ɔ. 246–247.
ıll. No. 1, 4th ser., 1903, p. 279.
Pa. 2d Geol. Surv. Rept., Vol. I⁵, p. 335.
ol. Surv. Bull. No. 1, 4th ser., 1903, p.

ibid., pp. 279–280.
ɔl. Surv. Bull. No. 1, 4th ser., 1903, p. 304.

[14] Ibid., Rept. 1888, vol. 6, p. 291.
[15] Ibid., pp. 289–290.
[16] Ibid., pp. 320, 377–378.
[17] Ibid., pp. 380–381.
[18] Ibid., pp. 654–655.
[19] Record, ibid., pp. 324, 381–382.
[20] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 221–223.
[21] Ibid., pp. 65–71.
[22] Ibid., Rept. 1888, vol. 6, p. 218.
[23] Ibid., Bull. No. 1, 4th ser., 1903, p. 69.
[24] Ibid., pp. 215–216.
[25] Ibid., p. 217.
[26] Ibid., Rept. 1888, vol. 6, pp. 122–133, 146; 1890: p. 125.
[27] Ibid., pp. 111–117.
[28] Ibid., pp. 131–132.

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Hancock County—Cont'd.					
Findlay	1,158	6			Water at 50 and 60 feet; brine at 540 feet; small amount of gas; well abandoned.
Marion Township[1]					Gas well.
McComb[2]	1,455				Gas well with salt water.
Mount Blanchard[3]					Moderate flow of oil and gas.
Portage Township[4]	+1,201				
Do	1,414				Smith farm well No. 8: oil.
Rawson[5]	1,337				For gas or oil; found salt water only.
Stuartsville Township[6]	450				Oil wells.
Vanburen (west of)[4]	+1,232				Oil well.
Vanlue[2]	1,294				Small flow of gas.
Hardin County:					
Ada[7]	1,384–1,820				Several wells for gas: some successful; others yield only flows of salt water.
Dunkirk[8]	1,565			−445	For gas; only salt water found.
Do.[9]	1,870				Large flow of oil.
Forest[8]	1,470				Unsuccessful.
Forest (3 miles southwest).	480		Many.	Flows.	White sulphur water.
Kenton[10]	1,600				Unsuccessful.
Do					Do.
Paterson (2 miles south)[11]	1,330				Gas at 835 feet; large flow of water.
Paterson (2 miles west)[12]	1,300				Large flow of gas: also large flow of water.
Harrison County:					
Archer Township	1,308–1,418				
Cadiz Township	1,400–1,567				Several wells; some gas.
Cadiz (1 mile north of court-house).[13]	1,464				Strong flow of brine; no oil.
Cadiz (east of)[14]	1,400				Small flow of oil, and considerable gas.
Cadiz (1 mile north)[15]	1,151				Dry hole; first well near Cadiz.
Cadiz (one-half to 1 mile east).[15]	1,036–1,072				3 wells; 2 produce gas.
Cadiz (1 to 2 miles southeast).[15]	1,022–1,144				Do.
Cadiz (1½ to 2 miles east)[15]	1,133–1,220				3 unproductive wells.
Cadiz (1½ to 2 miles northeast).[15]	1,032–1,216				30 wells: some gas and oil.
Cadiz (1 mile northeast)[15]	1,150				Dry.
Celeran Township	1,627				Gas.
Cross Creek Township	1,411				Do.
Fife (vicinity)[15]	1,198				
Do.[15]					3 wells.
Fife (1 to 1½ miles west and northwest)[15]	1,081–1,285				Many wells.
Franklin Township	1,076				
Freeport Township	1,191				
German Township	1,306–1,419				
Germano (vicinity)[15]	1,152				
Germano (1½ miles south).[15]	1,118				
Germano (2 miles southwest).	1,041				
Green Township	1,353–1,680				Many wells; some gas.
Greenough (1 to 1½ miles south).[15]	1,023–1,069				2 wells; unsuccessful.
Greenough (1 mile west).[15]	1,096–1,195				3 dry wells.
Greenough (vicinity)[15]	1,029–1,225				9 wells.
Greenough (½ to 1½ miles north).[15]	1,075–1,230				19 wells; some oil.

[1] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 236.
[2] Ibid., p. 219.
[3] Ibid., p. 218.
[4] Ibid., Bull. No. 1, 4th ser., 1903, p. 69.
[5] Ibid., Rept.., 1888, vol. 6, p. 217.
[6] Ibid., 1890, pp. 219–220.
[7] Ibid., p. 219; 1890, pp. 184–186.
[8] Ibid., p. 223.
[9] Ibid., 1890, p. 186.
[10] Ibid., p. 220.
[11] Record, ibid., Rept. 1888, vol. 6, pp. 221–222.
[12] Ibid., p. 222.
[13] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 226.
[14] Ibid., pp. 227, 228.
[15] U. S. Geol. Surv. Bull. No. 198, 1902, pp. 25–33.

OHIO—Continued.

cation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
unty—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
gh (1 mile east)[1]					
gh (1 or 1½ miles ast).[1]					
ough (1 mile vest).[1]					
e (1 mile south)[1]	1,190				
le (southwest	1,512				
(near)[1]	1,148				Dry.
	1,110–1,152				2 wells; some oil.
(1 to 1½ miles ast).[1]	1,030–1,212				12 wells.
(1 mile north-	1,071				
tation (1 mile .[1]	1,025				
Township	1,038–1,250				Several wells.
ownship	1,100–1,540				Many gas and oil wells.
nam Township	1,278				Gas.
wnship	1,190				
Township	1,178–1,300				4 wells.
ar)[3]	1,190				
eek Township	1,435–1,580				Do.
le (vicinity)[1]	1,036				
le (1½ miles vest).[1]	1,107–1,213				Some oil with large quantities of salt water.
vale (1 mile	1,011				
ton Township	1,154				
ty:					
[4]	1,600				Only small flow of gas.
n[5]	1,889			+3	For gas; salt water at 1,889 feet.
ounty:					
o[6]	1,750				Good water at 1,750 feet.
unty:					
gville[7]	628				Small flow of oil.
					Two borings.
	625–689				Several wells; some oil, water, and gas.
	1,002				Some oil.
nty:					
(near)[9]	626–1,000				Several wells.
urg[10]	2,100				
urg (4 miles	900–1,000				Gas and oil well.
urg[11]	2,100				Oil and gas; free from salt water.
ty:					
[12]	1,700				For gas; unsuccessful.
Junction[13]	1,250				
ille[14]					Small flow of gas only.
ndon[15]	998–1,030				Three wells; nothing found except salt water.
[16]	2,304				
	2,725	5½			For oil or gas; unsuccessful. For oil; found salt water only at 1,950 feet.
n	3,000				
nty:					
[17]	1,600				Small flow of gas.
	1,636				Some gas; much salt water.
Township[18]	2,155				Abandoned.
[18]	800				Small show of oil and gas.
unty:					
dam (1 mile ast).[1]	961				Salt water.
rdam (1 to 1½ outhwest).[1]	945–1,070				3 wells.
am (vicinity)[1]	933				
ld station (vi- .[1]	1,067				

l. Surv. Bull. No. 198, 1902, pp. 25–33.
Ohio Geol. Surv. Bull. No. 1, 4th ser.,

238.
pt. 1888, vol. 6, p. 253.
. 252–253.
. ibid., p. 297.
ibid., pp. 393–394.
. 318, 392–393.
l. Surv. Bull, No. 1, 4th ser., 1903, pp.

[10] Ibid., Rept., 1888, vol. 6, pp. 367–368.
[11] Record, ibid., Bull. No. 1, 4th ser., 1903, p. 288.
[12] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 214–215.
[13] Ibid., pp. 350–351.
[14] Ibid., pp. 439–440.
[15] Ibid., pp. 348–350, 440.
[16] Ibid., pp. 440–441.
[17] Ibid., pp. 319–394.
[18] Ibid., Bull. No. 1, 4th ser., 1903, p. 275.

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Jefferson County—Cont'd.					
Bloomingdale (1 mile north).[1]	918–939				2 wells; the deeper one is a gas well.
Bloomingdale (1 mile west).[1]	1,038				
Brush Creek Township	800–1,189				2 wells.
Cross Creek Township	1,190–1,662				Gas wells.
Fairplay (1 mile northeast).[1]	911				
Germano (2 miles northeast).[1]	1,052				
Island Creek Township[2]	1,241				
Do	1,050–1,417				4 wells.
Knox Township	904–1,455				3 wells.
Mount Pleasant Township.	1,620–1,726				2 wells.
Piney Fork (1 mile west)[1]	979				
Piney Fork (1½ miles northwest).[1]	988–991				2 wells; some oil.
Richmond (2 miles northeast).[1]	880				
Salem Township[2]	1,157				
Saline Township	1,105				Unproductive.
Smithfield Township[4]	1,607				
Do	1,451–1,810				5 wells.
Smithfield (1½ miles west).[1]	1,039				
Smithfield (vicinity)[1]	1,038				
Smithfield (1 to 1½ miles south).[1]	1,002–1,234				6 wells.
Smithfield (1 mile southeast).[1]	1,073				
Smithfield (1½ miles northeast).[1]	918				
Smithfield Township	1,417				
Steubenville[5]	1,290				Transient gas supply.
Do.[6]	2,519				
Toronto (4 miles west)[7]	1,455				For oil; unsuccessful.
Warren Township	1,382–2,519				3 wells.
Knox County:					
Buckeye (east of)[8]					Gas wells.
Miller Township[9]					Several gas wells.
Mount Vernon[10]	1,370, 1,707, 2,600				3 wells; unsuccessful.
Do.[11]	3,200	4¼		100	Gas well; water at 1,725 and 1,765 feet.
Do	2,135				Unsuccessful.
Lake County:					
Painesville[12]	700–1,390				Several gas wells.
Willoughby[13]					Several small gas wells.
Lawrence County:					
Ironton[14]	3,600				Unsuccessful.
Licking County:					
Homer[15]					Several gas wells.
Do.[16]	2,345				
Newark[17]	1,449–2,385				Several gas wells; small flows.
Utica (7 miles west)	2,133	6¼			Gas well; water stratum at 215 feet.
Logan County:					
Belle Center[18]	+1,310				Very small flow of gas.
Bellefontaine[19]	1,590				Do.
De Graff[20]	1,356				Some oil and gas.
De Graff (1 mile west)	1,300	8–5⅛			
Huntsville	1,460				Gas well.
Lorain County:					
Belden (near)					Many oil wells.
Brownhelm[21]	635				Some oil.
Brownhelm[22]	740				A little gas and oil.

[1] U. S. Geol. Surv. Bull. No. 198, 1902, pp. 25–33.
[2] Record, Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 245.
[3] Record, Pa. 2d Geol. Surv. Rept. II, p. 282.
[4] Record, Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 248–249.
[5] Ibid., Rept. 1888, vol. 6, pp. 336–337.
[6] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, part 2, p. 784.
[7] Pa. 2d Geol. Surv. Rept. I[5], p. 236.
[8] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 340–343.
[9] Ibid., Bull. No. 1, 4th ser., 1903, pp. 117, 284–285.
[10] Record, ibid., Rept. 1888, vol. 6, pp. 217, 266–267.
[11] Ibid., 1890, pp. 244–245.
[12] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 427–428.
[13] Ibid., p. 428.
[14] Record, ibid., pp. 304–306, 319.
[15] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 109.
[16] Record, ibid., p. 120.
[17] Ibid., Rept. 1888, vol. 6, pp. 317, 370–372.
[18] Ibid., p 267.
[19] Ibid., ibid., pp. 266–267.
[20] Ibid., p. 268.
[21] Record, Pa. 2d Geol. Surv. Rept. II, p. 282.
[22] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 437–438.

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Lorain County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Brownhelm Township	635				
Elyria [1]	987				Small gas supply and heavy flow of salt and sulphur water.
Lorain [2]	+600			—50	Mineral water; some gas.
Sheffield [3]	720				Bored for oil; some gas found; unsuccessful.
Wellington [4]	1,030–1,050				Several small gas wells.
Lucas County:					
Oregon Township [5]					Several unsatisfactory oil wells.
South Toledo [6]	+1,012				Unproductive.
Toledo [7]	1,425				Several borings for gas and oil; unsuccessful.
Waterville [8]	1,153				Small flow of gas.
Madison County:					
Lafayette [8]					Unsuccessful.
London [9]	1,585				Several wells for oil or gas.
Plain City [10]	1,530–2,000	8		+13	Two wells; large flows of fine water from 350, 600, and 900 feet.
Mahoning County:					
Brier Hill [11]	500				Gas at 420 feet, but not in paying quantities.
Canfield (near) [12]	600				Only a show of oil.
Lowellsville [12]	1,800				Neither oil or gas.
West Austintown [12]	400				Several wells; small quantities of heavy oil.
Youngstown [13]	2,480				For gas or oil; unsuccessful.
Youngstown (3 miles southwest). [12]	2,075				Neither oil or gas in commercial quantities.
Youngstown (1 mile west). [12]	500				Unsuccessful.
Marion County:					
Marion [14]	1,790				Abandoned.
Martel	474				
Prospect [15]	1,650				No product.
Medina County:					
Lodi (near) [16]	1,670				
Medina [17]	917				Small flow of gas.
Meigs County:					
Middletown	950–1,250	3 and 4	Av. 25		Great number of salt-water wells in county.
Milan [18]	1,500				Small amount of oil from 120 to 1,500 feet.
New Lima (near)	1,000				Several wells; all made showing of oil.
Olive Township [19]	2,500				Showing of oil and gas; abandoned.
Pomeroy	1,550		20	500	Salt well; some oil and gas.
Do	1,100				Several salt wells; flowed originally.
Do [20]	767				
Salisbury Township [21]	1,780				Some gas, small show of oil; abandoned.
Rutland (1½ miles northwest). [21]	830				Oil in very small quantities; not saved.
Rutland (near) [21]	1,971				Unsuccessful.
Rutland Township	1,560		10–25	500	Salt water only.
Mercer County [22]					Many oil and gas wells; 81 per cent are producers.
Celina [23]	1,147–1,168				Gas wells.
Celina (southwest of) [24]					Oil well; produced 500 barrels of oil a day at first; one month later it yielded salt water only.

[1] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 347–348.
[2] Ibid., pp. 438–439.
[3] Record, ibid., p. 437.
[4] Ibid., pp. 348–349.
[5] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 92–93.
[6] Record, Rept. 1888, vol. 6, p. 225.
[7] Record, ibid., pp. 208–209, Mich. Geol. Surv., 1891–1893, p. 85.
[8] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 219.
[9] Ibid., pp. 280–281.
[10] Ibid., 1890, p. 246; U. S. Geol. Surv., 19th Ann. Rept., 1897–98, p. 663.
[11] Ibid., Bull. No. 1, 4th ser., 1903, p. 299.
[12] Ibid., p. 300.
[13] Ibid., Rept. 1888, vol. 6, pp. 321, 402–403.
[14] Record, ibid., pp. 201–202.
[15] Analysis, ibid., pp. 270–271.
[16] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 306.
[17] Ibid., Rept. 1888, vol. 6, p. 360.
[18] Ibid., Rept. 1888, vol. 6, p. 346.
[19] Ibid., Bull. No. 1, 4th ser., 1903, p. 283.
[20] Ibid., Rept. 1888, vol. 6, p. 397.
[21] Ibid., p. 282.
[22] Ibid., Bull. No. 1, 4th ser., 1903, pp. 89–92.
[23] Record, ibid., Rept., 1888, vol. 6, pp. 259–260.
[24] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 90.

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Mercer County—Continued.					
Center Township[1]					Initial production of 1,200 barrels of oil per day, which gradually decreased to a very small amount.
Coldwater (3½ miles east)	1,100	8–5½		(?) 15	
Fort Recovery[2]	1,052				Gas for several months.
St. Henry[3]	1,160–1,183				Gas well.
Miami County:					
Covington[4]					Small supply of gas.
Piqua[5]	1,673				For gas: unsuccessful.
Tippecanoe[6]	1,025				Small flow of gas.
Troy[6]	1,170				Some gas at 510, 630, and 880 feet.
Montgomery County:					
Dayton[7]	870				Some shale gas.
Do.[8]	2,440			200	
Miamisburg[9]	800–1,200				2 gas wells.
Monroe County:					
Barnesville (near)[10]	2,700				Oil well; failure; others sunk later which were fairly successful.
Bethel Township[11]	1,810				
Graysville Pool[12]	1,917 2,025				2 oil wells.
Griffith (near)[13]	1,258 2,031				Do.
Lewisville (2 miles northeast of).[14]	1,956				Oil well.
Martins Ferry[15]	2,300				Oil well; failure.
Moose Ridge Pool[16]	1,224				Oil well.
Newcastle (east of)[17]	1,595				Do.
Sardis (southwest of)[18]	1,815				Do.
Sisterville (opposite)[19]	1,895				Do.
Temperanceville (north of).[20]	1,631 2,200				Oil wells.
Washington Township[21]	2,234				
Wheeling Township[22]	1,546 1,610				Poor oil; wells abandoned.
York Township[23]	2,100–2,300				Several wells.
Morgan County:					
Eaglesport[23]	1,134				Salt water; abandoned.
Do	1,152	8–6			Oil rises to −40 feet.
Homer Township[24]	612				Gas well.
Do.[25]	1,300				
Joy[26]	1,240				2 wells; much salt water; only small flow of gas.
McConnellsville	3,000				For oil or gas: unsuccessful.
Do	1,330	7½–5½			Gas and salt water.
Do.[27]	3,186				For gas; unsuccessful.
Malta[28]					Large flow of gas from several wells, for oil or salt.
On Oliver Run[29]	413				
Shawnee Junction (near).[30]	+1,125 +1,175 +1,073				For oil or gas, unsuccessful.
Morrow County:					
Cardington[31]	+2,300				Small flow of gas.
Muskingum County:					
Brush Creek Township[32]	1,010–1,155				Gas, oil, and salt water.
Cass Township	768				Oil and brine, well abandoned.

[1] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 91–92.
[2] Ibid., Rept., 1888, vol. 6, pp. 263–264.
[3] Ibid., pp. 260–262.
[4] Ibid., 1890, p. 274.
[5] Ibid., Rept., 1888, vol. 6, p. 273.
[6] Ibid., p. 274.
[7] Record, ibid., p. 288.
[8] Ibid., p. 286.
[9] Ibid., pp. 288–289.
[10] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 214.
[11] Record, ibid., p. 208.
[12] Ibid., p. 203.
[13] Ibid., p. 201.
[14] Ibid., pp. 212–213.
[15] Ibid., p. 219.
[16] Ibid., pp. 205–206.
[17] Ibid., p. 210.
[18] Record, W. Va. Geol. Surv. Rept., vol. 1, pp. 356–357.
[19] Record, Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 196.
[20] Ibid., pp. 216–217.
[21] Ibid., p. 220.
[22] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 221.
[23] Ibid., Rept. 1888, vol. 6, pp. 389–390.
[24] Record, ibid., Bull. No. 1, 4th ser., 1903, pp. 133–134.
[25] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 139.
[26] Ibid., Rept. 1888, vol. 6, p. 390.
[27] Record, ibid., Bull. No. 1, 4th ser., 1903, pp. 145–146.
[28] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 389.
[29] Record, ibid., Bull. No. 1, 4th ser., 1903, p. 142.
[30] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 147–148.
[31] Ibid., Rept., 1888, vol. 6, pp. 283–284.
[32] Ibid., Bull. No. 1, 4th ser., 1903, p. 267.

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
·kingum County—Con'd.					
Dresden[1]	2,525				
Do.[2]	1,000				Unsuccessful.
High Hill[3]	1,700				Some oil; well abandoned.
Jackson Township[3]	760				Salt water; show of gas.
Newton Township[3]	+ 887				Some gas and oil; well abandoned.
Rich Hill Township[3]	1,350				Some oil.
Salem Township[3]	1,176–1,255				Showing of oil and gas; much salt water.
Salt Creek Township[3]	1,085				Unsuccessful.
Zanesville[4]	1,098–2,019				3 wells; some oil.
ble County:					
Belle Valley (near)[5]					Several oil wells.
Dexter (near)					
Dudley (near)[5]	+1,380				Gas well.
Jackson Township[6]	747½				
Moundsville[5]					2 wells; one dry, other furnished large amount of gas.
South Olive					Unproductive.
awa County:					
——[7]					Several oil and gas wells.
Elmore[8]	+1,250				2 oil wells.
Genoa[9]	1,308				Small flow of oil and gas.
Lacarne[9]	1,700				Much water.
Oakharbor[10]	+1,300				Well made showing of oil and furnished about 78,000 cubic feet of gas a day.
Do.[10]					Yielded 200,000 cubic feet of gas a day.
Oberlin	700				For oil or gas; unsuccessful.
Port Clinton[11]	+1,660				No product.
rry County:					
Junction City (near)[12]	+3,100				
McCuneville[13]	1,368				Several wells; bored for salt water; some found.
Somerset[14]	2,850			−400	Salt water at 2,850 feet.
·kaway County:					
Circleville					
ke County:					
Piketon					
eble County:					
Camden[15]	900				Gas well.
Eaton[16]	1,170–1,375				Several wells; unsuccessful.
itnam County:					
Columbus Grove[17]	1,278				Gas at 740 feet; some oil at bottom.
Fort Jennings	1,425	8		− 25	Salt water.
Kalida (1 mile north)[18]	1,316				Bored for oil; salt water found.
Leipsic[19]	1,456				Some oil and gas and great volume of salt water.
Ottawa[20]	1,314–1,365				Two oil and gas wells; small product; much salt water.
Richland County:					
Crestline[21]	2,864				
Mansfield[22]	2,005–2,415				2 borings for gas; unsuccessful.
Do.[23]	3,594	5–4			Unsuccessful.
Shelby[24]	1,480–1,796				Small flow of gas; 2 wells.
Richmond County:					
Plymouth[25]	742				
Do.[26]	3,020				Salt and sulphur water at 850 feet.

[1] Ohio Geol Surv Rept., 1890, vol. 6, p. 246.
[2] Ibid., 1888, vol 6, p. 376.
[3] Ibid., pp 268–269.
[4] Ibid., pp. 372–375.
[5] Ibid., Bull. No 1, 4th ser., 1903, p. 225.
[6] Record, ibid., 1903, pp. 160–161
[7] Ohio Geol. Surv. Bull. No 1, 4th ser., 1903, pp. 4–95
[8] Ibid., Rept 1888, vol. 6, pp. 211–212.
[9] Ibid., p. 213.
[10] Ibid., Bull No. 1, 4th ser., 1903, p. 94, 1888, ol 6, p. 210–211.
[11] Ibid., Rept. 1888, vol 6, p. 212.
[12] Record, ibid., Bull. No. 1, 4th ser, 1903, pp 8–119.
[13] Ohio Geol. Surv. Rept. for 1888, vol. 6, pp. 388–389
[14] Ibid., 1890, p. 247.
[15] Ibid., 1888, vol. 6, p. 285.
[16] Ibid., pp. 108, 284.
[17] Ibid., p. 242.
[18] Record, ibid., p. 243.
[19] Ibid., p. 242.
[20] Ibid., p. 241.
[21] Ibid., pp. 303–304.
[22] Ibid., pp. 318, 365–366.
[23] Ibid., 1890, p. 245.
[24] Ibid., 1888, vol. 6, pp. 316, 364–365.
[25] Ibid., p. 315
[26] Ibid., pp 302–303.

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Sandusky County[1]					Many oil wells
Clyde[2]	1,850				Unsuccessful.
Freemont and vicinity[3]	1,300–1,500				Several gas wells.
Do.[4]	568				Gas well.
Do.[5]	+1,328				Do.
Gibsonburg[6]	+1,287				Produced 50 barrels of oil per day.
Do.[6]					Gas well; pressure of 300 pounds per square inch; other wells completed with similar results.
Lindsey[7]	1,241–1,300	4			3 oil and gas wells; also flow; salt water in large quantities.
Madison township					Produced 2,000 barrels of oil a day.
Rollersville (near)[8]	+1,252				
Roseville (near)[9]	1,252				For oil or gas.
Tinney (south of)	1,220	8–5½		−10	Gas, oil, and salt water.
Washington Township[10]					Gas well; original rock pressure exceeded 400 pounds.
Woodville[11]	1,460				For oil or gas; only salt water found.
Do.[12]	+1,184				Oil in paying quantities.
Woodville (near)[13]					Produced 2,500 barrels of oil a day.
Scioto County:					
Portsmouth[14]	2,000				No product, but salt water at 1,000 feet.
Barden	1,710	10		−510	Water.
Sciotoville	800				Unsuccessful.
Seneca County[15]					Many oil and gas wells, 95 per cent producers.
Bloomville[16]	2,150				For oil; unsuccessful.
Fostoria[17]	1,136–1,775				Several gas wells.
Tiffin[18]	1,467–1,494				Several wells; large flow of gas; some oil.
Tiffin (vicinity)[19]	1,505–1,753				Several borings; all unsuccessful.
Shelby County:					
Kettlersville (near)[20]					2 oil wells.
Sidney[21]	1,205–1,250				Several gas wells; much salt water at 1,445 feet.
Stark County:					
Alliance (in and near)[22]	640 to +2,800				Some produced oil and gas; all short lived.
Canton[23]	2,220				For oil, but only salt water found.
Do	+3,135				
Louisville[24]	825				Gas and salt water.
Louisville (northwest of).[24]	+ 690				Gas pressure of 210 and 175 pounds; 2 wells.
Massillon[25]	655–1,820				Nothing but salt water.
Do.[26]	671				Some oil; also salt water.
Do.[26]	2,547				Gas at 655 feet, shut out by salt water.
Myers (1 mile north)[24]	797				Show of gas.
Robertsville (near)[24]	680				
Washington Township[24]	800				Dry.
	420				Much gas, but well was ruined by salt water.
Summit County:					
Akron[27]	2,250				
Do	2,450				Some gas at 172 feet.
Barberton[28]	3,006				For salt.
Coventry Township	800				Coal.
Northfield Township[28]	800				

[1] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 71–76.
[2] Record, ibid., Rept. 1888, vol. 6, p. 214.
[3] Ibid., pp. 183–189.
[4] Ibid., p. 188.
[5] Record, ibid., Bull. No. 1, 4th ser., 1903, p. 74.
[6] Ibid., p. 72.
[7] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 213, 788–789.
[8] Record, ibid., Bull. No. 1, 4th ser., 1903, p. 74.
[9] Ibid., p. 19.
[10] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 72.
[11] Ibid., Rept. 1888, vol. 6, pp. 213–214.
[12] Ibid., Bull. No. 1, 4th ser., 1903, pp. 71–72.
[13] Ibid., p. 75.
[14] Ibid., Rept. 1888, vol. 6, p. 395.
[15] Ibid., Bull. No. 1, 4th ser., 1903, pp. 76–78.
[16] Ibid., Rept. 1888, vol. 6, p. 201.
[17] Ibid., pp. 192–193, 146, 231.
[18] Record, ibid., pp. 197–201.
[19] Ibid., 1890, pp. 784–785.
[20] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 99.
[21] Record, ibid., Rept. 1888, vol. 6, pp. 264–266.
[22] Ohio Geol. Surv. Bull. No. 1, 4th ser., p. 298.
[23] Record, ibid., Rept. 1888, vol. 6, pp. 359–360.
[24] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 299.
[25] Ibid., Rept. 1888, vol. 6, pp. 320, 361.
[26] Ibid., p. 360.
[27] Record, ibid., p. 319.
[28] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 296.

OHIO—Continued.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
unty:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
d[1]	1,800				Dry.
	3,710				Little oil, gas, and salt water at 2,995 feet; top of salt at 3,239 feet.
	780–900				2 borings for gas; unsuccessful.
ca (near)[1]	1,100 1,300 2,300				3 wells; unsuccessful.
County:					
ver Township	894				Coal and brine.
ver[3]	2,760				Little gas and salt water.
(near)[4]	1,400				Small show of gas.
near)[4]	1,200				Several wells.
nship	460				
wnship[5]	1,509				Some oil and gas.
y:					
Springs[6]	1,600				Salt well.
e[7]	1,743				For gas or oil; found only water at 300 feet.
unty:					
					Several oil and gas wells.[8]
	1,240				Very small flow of gas.
ty:					
ownship	1,000	10–5			Oil, gas, and salt water.
lls	600				Salt water.
	780				Nothing but salt water.
	1,100				Salt water, some oil.
r	900–1,000				Fresh and salt waters.
Township	1,017	10–5			Very little oil and salt water.
ove (25 miles o	2,860				
Township[11]	2,449				
	700 or 800				Water and gas.
Township[12]	2,340				Gas well.
vnship[13]	2,900 2,811				2 wells.
ownship[14]	490–1,057	10–5			Gas, oil, and salt water.
	1,052				Salt water and gas.
ty:					
[16]	700–1,300				Small flow of gas; much salt water.
County:					
Township	1,114				
	+1,740				
Mills (3 miles est).[18]	473 447				2 wells.
[19]	+1,375				For oil or gas; unsuccessful.
	594				Oil well (schoolhouse).
	+ 423				Oil well.
Pool[22]	2,138				Do.
ills Pool[23]	1,400 1,823				
Township[24]	1,650–1,800				3 wells, produced small amount of oil.
	1,017				
g[25]	400–1,700				Large oil field about here.
	2,100				Numerous successful wells; gas found also.
	2,500				Oil and gas.
g (near)[22]	702				For gas or oil.
	905				Do.

l. Surv. Bull. No. 1. 4th ser., 1903.
. Surv. Rept., 1888, vol. 6, p. 401.
l. No. 1, 4th ser., 1903, pp. 320, 369–370.
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0.
id., Rept. 1888, vol. 6, p. 269.
69–270.
. Surv. Bull. No. 1, 4th ser., 1903, pp.
id., Rept. 1888, vol. 6, pp. 239–240.
record, ibid., Bull. No. 1, 4th ser.,
bid., p. 287.
. Surv. Bull. No. 1, 4th ser., 1903, p. 277.
278–279.
t. 1888, vol. 6, p. 394.

[15] Record, ibid., Bull. No. 1, 4th ser., 1903, pp. 276–277.
[16] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 295–296.
[17] Ibid., p. 218.
[18] Record, ibid., Bull. No. 1, 4th ser., 1903, pp. 135–136.
[19] Ibid., pp. 168–169.
[20] Ibid., pp. 165–166.
[21] Ibid., p. 27.
[22] Skeleton record, ibid., p. 186.
[23] Record, ibid., p. 190.
[24] Ibid., pp. 170–171.
[25] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 450–464.
[26] Ibid., p. 453.
[27] Record, Pa. Geol. Surv. Rept., Vol. I[5], pp. 333–334.
[28] Ibid., p. 28.

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Washington County—Cont'd.					
Macksburg (near) [1]					Many oil wells
Do. [2]	1,695				
Marietta [3]	1,740-2,940				Oil wells.
Marietta (4 miles below). [4]	1,440				Gas well.
Marietta (near) [5]	3,015				Much salt water at 1,700 feet.
Do. [6]	+ 546				For oil or gas.
Marietta [7]	2,008				Do.
	2,740				
Moores Junction [8]	1,440				Oil well.
Newport Township	601				
Wingett [9]	+1,687				Gas well.
Township unknown	1,576				2 oil wells.
	2,500				
Wayne County:					
Orrville	604	4¼			Brine at 227 and 588 feet.
Wooster [10]	1,805-2,000				3 borings for oil or gas; unsuccessful.
Sterling [11]	+ 400				Gas-well boring.
Williams County:					
Bryan [12]	1,974-2,037				Gas and oil wells; yield small; salt water at 2,037 feet.
Stryker	860				Mineral water at 220 feet.
Wood County [13]					Many oil wells; 88 per cent producers.
Bairdstown	1,058				Gas wells.
Bairdstown (1½ miles north). [14]	1,154				Gas well.
Bairdstown (near) [15]	1,154				For gas; abandoned.
Bloomdale [16]	1,115				Large flow of gas.
Bowling Green [17]	±1,300				Gas well.
Do. [18]	1,152				Large volume of gas.
Do [19]	1,648				Oil well.
Bradner [20]	1,244				Small flow of oil.
Hammansburg [21]	1,194				Do.
Haskins					Oil well.
Henry Township [22]	1,125-1,150				Gas wells; some oil.
Do. [23]	1,212-1,295				Oil.
Jerry City [24]	1,155				2 wells; one with fair supply of oil.
Liberty Township [25]					Produced 10,000 barrels of oil per day.
North Baltimore [26]	1,104½-1,295				2 gas and oil wells.
Do. [27]	1,190				
Pemberville					Unsuccessful.
Perrysburg [28]	+1,600				Several gas wells.
Portage (vicinity) [29]	1,177				
Do. [29]	1,134				Unsuccessful.
Do. [29]					Large flow of gas.
Portage (near)	1,262	8½-6½			Produces 5 barrels of oil a day.
Risingsun					Only small flow of oil.
Tontogany (2½ miles southeast).	1,425	8-5½		− 30	Some salt water, oil, and gas.
Weston [30]	1,575				Oil, gas, and sulphur water.
Wyandot County [31]					Several oil and gas wells.
Carey and vicinity [32]	1,826-1,500	5½			Several gas wells, some yield large supply.
Little Sandusky	1,450	8-5½		− 40	Salt water at 25 feet

[1] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 149-160.
[2] Record, ibid., pp. 161-162
[3] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 368-410.
[4] Record, W. Va. Geol. Surv. Rept., vol. 1, p. 288.
[5] Ibid., pp. 286-287
[6] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, p. 28
[7] Record, ibid., pp. 176-178.
[8] Ibid., p. 175.
[9] Ibid., p. 190.
[10] Ibid., Rept. 1888, vol. 6, pp. 361-363.
[11] U. S. Geol. Surv. Monograph No. 41, p. 558.
[12] Record, Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 247-249, 786.
[13] Ohio Geol. Surv. Bull. No. 1, 4th ser., 1903, pp. 55-56.
[14] Ibid., Rept. 1888, vol. 6, pp. 229-232.
[15] Ibid., pp. 232-233.
[16] Ibid., pp. 233-234.
[17] Ibid., pp. 156-159, pl., p. 112.
[18] Ibid., p. 160.
[19] Record, ibid., Bull. No. 1, 4th ser., 1903, p. 59.
[20] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 207.
[21] Record, ibid., p. 237.
[22] Ibid., pp. 237-238.
[23] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, part 2, p. 786.
[24] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 233.
[25] Ibid., Bull. No. 1, 4th ser., 1903, pp. 61-62.
[26] Ibid., Rept. 1888, vol. 6, pp. 228-229; Pa. 2d Geol. Surv. Rept., 1886, p. 786.
[27] Record, ibid., p. 228.
[28] Ibid., pp. 225, 788.
[29] Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 164-165, 228.
[30] Ibid., pp. 223-224.
[31] Ibid., Bull. No. 1, 4th ser., 1903, pp. 95-96.
[32] Ibid., Rept. 1888, vol. 6, pp. 203-207; ibid., Bull. No. 1, 4th ser., 1903, p. 96

OHIO—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Wyandot County—Cont'd.	*Feet.*	*Inches.*	*Gallons*	*Feet.*	
Nevada[1]	2,000				Nothing but salt water.
Salem Township[2]	1,323				Small flow of oil.
Upper Sandusky[3]	1,340–1,347½				Two borings for oil or gas; unsuccessful.
Miscellaneous:					
Oakharbor[4]	1,326–1,335				3 gas wells.
Whartonsburg[1]	1,427				For oil or gas; unsuccessful.
Wilmington[5]					

[1] Ohio Geol. Surv. Rept. 1888, vol. 6, p. 203.
[2] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, part 2, pp. 785–786.
[3] Ohio Geol. Surv. Rept., 1888, vol. 6, p. 202.
[4] Ibid., pp. 210–211.
[5] Ibid., pp. 296–297.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN OHIO.

Report of the Geological Survey of Ohio, volume 6, Economic Geology, 831 pages, plates, Columbus, 1888.

First Annual Report of the Geological Survey of Ohio (third organization), by Edward Orton, State geologist, 323 pages, plates, Columbus, 1890.

Water resources of Indiana and Ohio, by Frank Leverett: U. S. Geological Survey, Eighteenth Annual Report, 1896–97, part 4, pp. 423–559, plates, Washington, 1897.

Rock waters of Ohio, by Edward Orton: U. S. Geological Survey, Nineteenth Annual Report, 1897–98, part 4, pp. 633–717, plates, Washington, 1899.

Oil and gas, by Bownocker: Ohio Geological Survey, Bulletin 1, 4th series, 1903.

Berea grit oil sand in Cadiz quadrangle, Ohio, by W. T. Griswold: U. S. Geological Survey Bulletin No. 198, pages 25–33, 1902.

Glacial formations of Erie and Ohio basins, by Frank Leverett: U. S. Geological Survey Monograph, No. 41, Washington, 1902.

OKLAHOMA.

Location.	Depths.	Diameter.	Yield per minute.	Height of water.	Remarks.
Beaver County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Optima	498				No water.
Canadian County:					
Fort Reno	1,200				
Do	1,370				Fresh water at 441 feet.
Do	1,445	12–7		No flow.	Alkaline and salty.
Comanche County:					
Lawton (T. 2, R. 11, sec. 22).	600	10–8			No water; natural gas at 350 and 575 feet.
Lawton (T. 2, R. 11, sec. 23).	1,415				Not completed; water sand at 638 and 950 feet, no flow; gas at 600 feet; water at 950 feet would rise about 500 feet; top water soft and fresh, lower is brackish; temperature at mouth, about 60°.
Cleveland County:					
Cleveland	504, 520				Bored for oil.
Garfield County:					
Garber (T. 23, R. 3, sec 18).	600	10			Not completed; no water; excellent samples of oil passed through.
Greer County.					
Granite (T 5, R. 21, sec. 33).	900	10–6		No flow.	Water found in sand; principal supplies at 15 and 750 feet.
Mangum	500				For oil, unsuccessful.
Do	400				Abandoned.
Kay County:					
Blackwell (one-half mile east from post-office).	1,630	4½		– 10	Water salty; vein of salt water at 1,630 feet producing 30 per cent of dry salt of remarkable purity.

OKLAHOMA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Kay County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Blackwell (50 rods northwest).					Gas at 500 and 860 feet.
Newkirk	1,115				Some oil, but not in paying quantities; salt water at various depths
Kingfisher County:					
Kingfisher	600			− 8	Large supply of strong salt water.
Oklahoma County:					
Oklahoma	780				For oil or gas; unsuccessful.
Osage County:					
Pawhuska	1,700				Oil well.
Pawnee County:					
Cleveland	520			− 40	For oil or gas; salt water at 220 feet.
Pottawatomie County:					
Shawnee	672				For oil or gas.
Woods County:					
Alva	491				Hard water, useless for boiler purposes (at depot).
Jet	975				At 280 feet is an 8-foot layer of sand, producing 1 to 3 barrels of oil daily; soft water at 180 feet.

OREGON.

Baker County:					
Baker City	400		Many.		
Clatsop County:					
Fort Stevens	400				Unsuccessful.
Do	800				Do.
Gilliam County:					
Blalock	400				Do.
Harney County:					
Burns	750	8			Abandoned; only a very small flow at 300 feet.
Morrow County:					
Heppner	650				
Multnomah County:					
Portland	1,850				
Wasco County:					
The Dalles	1,020	4¼-1¼			Bored for oil; no water below 350 feet.
A. M. Kelsay's farm	+1,002				Not completed.
Bliss water station	418	4-3¼	42	+10	Water tepid.
Cleft water station	425	3	+28	+10	Do.

PENNSYLVANIA.

Adams County—Continued.					
Littlestown	500				
Allegheny County:					
Allegheny	1,760				Salt well.
Do (?)	555–561				2 wells.
Bridgeville (vicinity) [1]	2,250				
Brushton Station	1,615				Unsuccessful.
Carnegie (near)	2,305				Gas well.
Collier Township [2]	2,019–2,400				3 wells; 2 gas wells.
Crescent Township [3]	2,106				For oil or gas; unproductive.
Dana Township	1,300				Gas.
Demmler	1,600				For oil or gas; abandoned.
Dixmont [4]	1,802				Oil and gas well.
East Deer Township	1,610–2,334				11 wells, some gas and oil
Do. [5]	1,194–1,243				Several gas wells; one abandoned.
Elrod	+1,500				For oil or gas, abandoned.
Do. [6]	1,486			Flows.	For oil or gas; unsuccessful.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 272.
[2] Ibid., pp. 261–262.
[3] Ibid., pp. 264–265.
[4] Ibid., pp. 257–258.
[5] Ibid., pp. 237–238.
[6] Ibid., 1886, pt. 2, pp. 667–668.

PENNSYLVANIA—Continued.

ion.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
ity—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
le north)	1,510	.....	.....	.....	For gas; abandoned.
ship.....	1,639–1,975	.....	.....	.....	19 wells; some gas and oil.
.....	2,000–3,118	.....	.....	.....	6 wells; some gas and oil.
ownship [1]....	1,905–2,150	.....	.....	.....	Several oil or gas wells.
.....	1,492 to ±1,500	.....	.....	.....	For oil or gas.
Township part).	2,030–2,385	.....	.....	.....	Many wells; for oil or gas.
Township adwaters of un).[3]	2,960	.....	.....	.....	Gas well.
[4]	±1,600	.....	.....	.....	For oil or gas; abandoned.
ne-half mile	2,017	.....	.....	.....	For oil or gas.
ownship.....	1,300–2,106	.....	.....	.....	6 gas wells.
wnship	1,852–2,300	.....	.....	.....	5 gas and oil wells.
wnship[6].....	1,109–1,200	.....	.....	.....	Several gas wells.
.....	1,205–2,300	.....	.....	.....	4 wells; some gas.
(vicinity)[7] ..	1,744	.....	.....	.....	For oil or gas.
ion (near)...	.....	.....	.....	.....	For gas; unsuccessful.
vnship.....	1,541–1,991	.....	.....	.....	20 gas and oil wells.
.....	2,002–2,418	.....	.....	.....	12 gas and oil wells.
.....	1,724	.....	Many.	Flows.	Fresh water at 1,600 feet.
wnship[9].....	2,014	.....	.....	.....	Gas well.
ell Township.	1,914	.....	.....	.....	Do.
irTownship.	1,403	.....	.....	.....	Do.
Township[10].	2,110	.....	.....	.....	For oil or gas.
ol Field[11]....	2,342	.....	.....	.....	
Borough....	1,610	.....	.....	.....	Gas well.
wnship[12]....	1,830	.....	.....	.....	
nship.....	2,471	.....	.....	.....	Unproductive.
.....	1,655	.....	.....	.....	For oil or gas; unsuccessful.
(1 mile).[14]	1,798	.....	Many.	Flows.	Fresh water.
ship[15].....	1,800–2,337	.....	.....	.....	Several oil and gas wells.
nd[16].....	1,686–1,837	.....	.....	.....	Do.
ailles (town-	1,850	.....	.....	.....	
tion (3 miles	2,164	.....	.....	.....	For oil or gas.
wnship	1,686–1,950	.....	.....	.....	Gas and oil.
.....	2,182	.....	.....	.....	
.....	1,950–2,060	.....	.....	.....	For oil or gas; unproductive.
hip[19].....	1,715–2,240	.....	.....	.....	Numerous gas and oil wells.
nship.....	1,798	.....	.....	.....	
ship[20].....	1,750	.....	.....	.....	For oil or gas; unproductive.
hip[21].....	2,010	.....	.....	.....	2 gas and oil wells.
miles south-	5,575	6¼	.....	.....	No water below 1,100 feet; deepest well in the United States.
ang avenue r street).[23]	4,700?	.....	.....	.....	For oil or gas; abandoned.
Twenty-first	1,616	.....	.....	.....	Gas well.
.....	1,620	.....	.....	.....	For oil or gas; abandoned.
Twenty-fifth	3,000	5⅝–5¼	.....	.....	Large gas well.
(Twenty- rd).[25]	1,826	.....	.....	.....	Gas well.

2d Geol. Surv. Rept., Vol. I², pp.

, p. 144.

. Geol. Surv. Folio No. 94, 1903.

2d Geol. Surv. Ann. Rept., 1886,

.

, p. 242.

-686.

1-746.

8-749.

2-753.

, p. 254.

Va. Geol. Surv. Rept., vol. 1, 1899,

1 (a), 1904, pp. 112-114.

2d. Geol. Surv. Ann. Rept., 1886.

13.

1-742.

[14] Ibid., pp. 746-747.

[15] Ibid., Vol. I³, pp. 263-268.

[16] Ibid., pp 258-260.

[17] Ibid., pp. 262-263.

[18] Ibid., pp. 239-241.

[19] Ibid., pp 244-251 W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 97-98.

[20] Ibid., 1886, part 2, pp. 749-750.

[21] Ibid., Vol. I³, pp. 243-244.

[22] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 103-107.

[23] Record, Pa. 2d Geol. Surv. Rept., Vol. I², pp. 276-277.

[24] Ibid., 1886, part 2, pp. 730-732; W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 99-101.

[25] Ibid., pp. 733-736

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Allegheny County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Pittsburg (Fourteenth Ward).[1]	2,007	5¼			Dry hole.
Pittsburg (near steel works).[2]	2,360				For oil or gas.
Pittsburg (just outside of city).	1,901				Gas well.
Do	1,600				Small flow of gas.
Pittsburg (Thirty-fourth Ward).[3]	2,014	5¼			For gas; unsuccessful, owing to salt water.
Pittsburg (Twenty-first Ward).[4]	1,635				
Pittsburg (Twenty-third Ward).	1,600				For gas; flooded with salt water.
Pittsburg (Thirty-third Ward).[5]	1,577				For oil or gas; abandoned on account of salt water.
Pittsburg (Fifteenth Ward).[6]	1,576				For oil or gas; abandoned.
Pittsburg (Twenty-first Ward).	1,575				For gas; flooded with water.
Pittsburg (Twenty-sixth Ward).	1,535				For oil or gas; abandoned on account of salt water.
Pittsburg	2,518				
Richland Township	1,597-1,866				5 gas wells.
Do	2,014-2,085				3 wells; 2 gas.
Robinson Township[7]	1,770-2,427				2 oil and gas wells.
Ross Township[8]	1,915-2,037				3 wells; some gas.
Sewickley Township[9]	2,008-2,133				Gas and oil wells.
Shaler Township[10]	1,393				For gas; abandoned.
Do	1,391				Gas.
Do	1,655-1,949				6 wells; gas and oil.
Do	2,050-2,250				2 gas wells.
Sharpsburg (near)[11]	2,010				For oil or gas; abandoned.
Snowden Township[12]	2,348				Gas well.
Sodom (near)[13]	2,275-2,502				Several gas wells.
South Fayette Township.[14]	2,140				Oil well.
South Versailles Township.	1,500-1,724				3 wells.
Do	1,550				Gas well.
Do.[15]	1,510-1,624				For oil or gas; abandoned on account of salt water.
Spence Run[16]	1,990				For oil or gas.
Springdale Station (near).	900				For gas; unsuccessful.
Tarentum	+1,160				For gas or oil; abandoned.
Tarentum (vicinity)[17]	482-1,705				Several gas and oil wells; small production.
Tarentum (3¼ miles northeast).[18]	2,010				For oil or gas; unproductive.
Toby Township	1,400				
Upper St. Clair Township.[19]	2,442				Gas well.
Do	2,250-2,502				3 wells; some gas.
Wall Station (near)	1,850		Many.	Flows.	Water charged with sol[illegible] temp., 65°-70°; also [illegible] well.
West Deer Township	1,425-1,971				26 wells; principally [illegible] and oil.
Do.[20]	2,004-2,243				8 wells; some gas and [illegible].
Do.[21]	2,243				For oil or gas, unproductive.
Township unknown	482				
Do	1,520-1,837				12 wells; some gas.
Do	2,007-2,425				5 wells; some gas; 3 [illegible] productive.
Do	3,000-4,618				2 wells; 1 gas, 1 unproductive.
Armstrong County:					
Bethel Township	1,082-1,168				3 wells; 1 gas.
Do	1,678-1,940				7 wells; 3 gas.
Do	2,223-2,273				2 wells; 1 unproductive, 1 gas.

[1] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, pt. 2, pp. 736-737.
[2] Ibid., Vol. III, pp. 398-400.
[3] Ibid., 1886, part 2, pp. 739-741; W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 101-103.
[4] Ibid., Vol. I[5], pp. 275-276.
[5] Ibid., 1886, part 2, p. 738.
[6] Ibid., p. 741.
[7] Ibid., Vol. I[5], pp. 268-269.
[8] Ibid., pp. 255-257.
[9] Ibid., p. 243.
[10] Ibid., 1886, pt. 2, pp. 752-753.
[11] Ibid., Vol. I[4], pp. 138-139.
[12] Ibid., Vol. I[5], pp. 273-274.
[13] Ibid., pp. 269-273.
[14] Ibid., p. 273.
[15] Ibid., 1886, pt. 2, pp. 751-752.
[16] Ibid., p. 744.
[17] Ibid., Vol I[3], pp. 405-408.
[18] Ibid., Vol. I[5], pp. 238-239.
[19] Ibid., pp. 271-272.
[20] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 96-97.
[21] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 241.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Armstrong County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Boggs (?) Township	898				
Boggs Township	772-907				6 wells; 3 gas.
Do	1,025-1,460				25 wells; 17 gas.
Do	1,560-1,771				3 wells.
Do	2,270-2,804				6 wells; 5 gas, 1 unproductive.
Bradys Bend	+1,089				Oil and gas well.
Bradys Bend Township[1]	1,100-1,260				For oil.
Do	1,456-3,500				9 wells; some oil and gas.
Burrell Township	900				Gas.
Do	1,172-1,478				29 wells; principally gas.
Do	1,500-1,980				26 wells; 18 gas.
Do	2,006-2,819				4 wells; 3 gas, 1 unproductive.
Cowanshannock Township.	1,120-1,480				40 wells; 33 gas.
Do	1,500-2,040				20 wells; mainly gas.
Criswell (vicinity)[2]	1,394-1,618				Oil and gas wells.
East Franklin Township.	861-971				5 gas wells.
Do	1,100-1,470				10 wells; 5 gas.
Do	1,504-1,892				7 wells; 3 gas, 3 unproductive.
Do	2,266				Gas well.
Farrentown[3]	1,140-1,166				Several oil and gas wells.
Fawn Township	1,147-1,550				Several good gas wells.
Foxburg[4]	806-944				Small oil wells.
Gilpin Township (?)	1,775				Unproductive.
Do	1,600-3,211				7 wells; 6 gas, 1 unproductive.
Kiskiminitas Township	1,314-2,031				15 wells; some gas and oil.
Kittanning Township	1,126-1,498				15 gas wells.
Do	1,511-1,975				23 wells; 22 gas.
Do	2,002-2,195				7 wells; 6 gas, 1 unproductive.
Lawrenceburg (south of)[5]	1,017				
Limestone Township (?)	895-1,730				10 wells; 7 gas.
Madison Township	872				Gas well.
Do	1,027-2,505				18 wells; principally gas.
Mahoning Township	1,725-2,719				3 wells.
Manor Township	1,175-2,036				25 wells; some gas.
North Buffalo Township.	1,017-2,910				38 wells; some gas.
Park Township	2,000-2,097				2 wells.
Parker City[6]	850				Oil well.
Perry Township[7]	801-950				For gas or oil, 7 wells.
Do.[8]	791				Oil and gas well.
Do	1,017-1,621				8 wells; some oil.
Pine Township	915-975				2 wells.
Do	1,000-2,625				11 wells.
Do.[9]	1,410-1,693				Oil and gas wells.
Plum Creek Township	1,100-2,965				54 wells, principally gas.
Rayburn Township	1,228-1,901				3 wells; 2 gas.
Redbank Township	1,100-2,231				10 wells; some gas.
South Bend Township	632,947				2 wells; 1 gas, 1 unproductive.
Do	1,100-2,078				22 wells; principally gas.
South Buffalo	1,094-2,890				47 wells; principally gas.
Sugar Creek Township	1,079-2,525				27 wells; some gas.
Valley Township	850-900				2 gas wells.
Do	1,093-1,605				28 wells; principally gas.
Washington Township	895-900				2 gas wells.
Do	1,175-2,316				6 wells; 5 gas.
Wayne Township	775-998				15 wells; 11 gas.
Do	1,004-2,681				39 wells; principally gas.
West Franklin	908				
Do	1,149-2,003				15 wells; principally gas.
Do.[10]	2,581-3,517				5 wells.
Beaver County:					
Baden (1 mile north)[11]	1,366				For oil or gas.
Beaver Falls[12]	2,330				For oil or gas; unsuccessful.
Beaver Falls (2 miles above).[13]	982				Gas well.
Bridgewater (near)					For gas; sn all supply.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. II, pp. 258-259.
[2] Ibid., pp. 253-258.
[3] Ibid., pp. 242-243.
[4] Ibid., pp. 237-238.
[5] Ibid., p. 243.
[6] Ibid., p. 242.
[7] Ibid., pp. 240-241.
[8] Ibid., Vol. III, pp. 416-417.
[9] Ibid., pp. 409-410; Vol. II, p. 277.
[10] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 108-112.
[11] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 232.
[12] Ibid., Vol. III, pp. 401-404.
[13] Ibid., Vol. I[4], pp. 142-143.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Beaver County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Darlington [1]	2,444				For oil or gas; unproductive.
Fairoaks [2]	1,645				Small oil well.
Fairoaks (vicinity) [3]	1,606				Gas well.
Georgetown [3]	1,430				For oil or gas; abandoned.
Hanover Township [4]	1,644				
Homewood station	1,500(?)				For oil or gas.
Homewood station (vicinity). [5]	925				Do.
Hopewell Township [6]	1,490–1,572				
Independence Township. [7]	+1,223				For oil or gas; unproductive.
Moon Township [8]	1,257–1,680				Several oil or gas wells.
New Sewickley Township. [9]	1,820				For oil or gas; unproductive.
Rochester [10]	965				For gas and oil.
Smiths Ferry [11]	500				For oil or gas; unproductive.
Bedford County:					
Osterburg (2 miles northwest).	800			+3	
Blair County:					
Altoona	2,006				Abandoned.
Bradford County:					
Hollenback	600				
Bucks County:					
Doylestown	750				
Revere [12]	2,084				Dry.
Butler County:					
Adams Township	1,900				Unproductive.
Do	1,285–1,831				56 wells; oil and gas.
Allegheny Township [13]	1,055–1,408				Oil and gas wells.
Brady Township [14]	1,458–1,598				For oil.
Brewster Field	1,640				
Buffalo Township	1,480–2,818				33 wells; mostly gas and oil.
Do	3,055				Unproductive.
Butler [15]	3,055				For oil or gas; abandoned.
Do	1,500–1,950				Several oil and gas wells.
Butler (3 miles south)	3,008	5			
Do [16]	1,500–1,795				Gas and oil wells.
Butler Township [17]	1,524–1,637				For oil.
Do	1,420–1,498				9 wells; 6 oil.
Do	1,883–3,008				Many wells; mostly gas and oil.
Center Township	1,640				
Clearfield Township [18]	1,558–1,925				Several oil and gas wells; one unsuccessful.
Do	400				Oil.
Do	2,612				Gas.
Clinton Township	1,140–2,709				34 wells, oil and gas; some unproductive.
Concord Township	1,120–1,676				8 wells.
Connoquenessing Township.	1,072–1,857				129 wells; gas and oil; some unproductive.
Cranberry Township	1,124–1,746				18 wells; oil and gas.
Donegal Township	680				
Do	1,362–1,491				18 wells; 6 oil.
Do. [19]	1,565–1,740				Many oil and gas wells.
Euclid Township					
Fairview Township	460–900				2 wells.
Do. [20]	1,421–1,694				Numerous oil and gas wells.
Do	1,341–2,460				58 wells; 26 oil.
Do. [21]	2,257				Well No. 1 on M. G. Bl[illegible] farm.
Forward Township [22]	1,553–1,683				Oil and gas wells.
Do	1,096–1,499				159 wells; 1 gas, 119 [illegible] 13 oil and gas.

[1] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, part 2, pp. 780–781.
[2] Ibid., Vol. I[5], pp. 232–233.
[3] Ibid., p. 233.
[4] Ibid., pp. 235–236.
[5] Ibid., Vol. QQ, pp. 250–251.
[6] Ibid., Vol. I[5], pp. 234–235.
[7] Ibid., 1886, part 2, pp. 779–780.
[8] Ibid., pp. 688–689.
[9] Ibid., Vol. I[5], pp. 231–232.
[10] Ibid., Vol. II, pp. 279–280.
[11] Ibid., pp. 281–282.
[12] Record, Ann. Phil. Soc. Trans., vol. 29, pp. 21–24.
[13] Record, Pa. 2d Geol. Surv. Rept., Vol. II, p[illegible] 238–240.
[14] Ibid., Vol. G[4], pp. 150–151; Vol III, pp. 418–4[illegible]
[15] Ibid., Vol. I[5], pp. 193–194.
[16] Ibid., pp. 209–210.
[17] Ibid., 1886, part 2, pp. 711–718.
[18] Ibid., p. 178; Vol. II, pp. 266–268.
[19] Ibid., Vol. I[5], pp. 199–203; Vol. II, pp. 263–26[illegible]
[20] Ibid., Vol. II, pp. 246–262.
[21] Record, W. Va. Geol. Surv. Rept., vol. 1 (a [illegible] 1904, p. 94.
[22] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], p. 20[illegible]

PENNSYLVANIA—Continued.

cation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
ty—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Township.....	1,500–1,809	.....	.....	.....	88 wells; 2 gas, 51 oil, 4 oil and gas.
.....	2,625	.....	.....	.....	Oil and gas.
elt City (vicin-	1,875	.....	.....	.....	
City (3 miles	1,500	.....	.....	.....	For oil or gas; unproductive.
ity (vicinity)[3]..	1,423–1,580	.....	.....	.....	Several oil and gas wells.
lle (vicinity)[4]..	880–1,367	.....	.....	.....	For gas or oil.
[5].....	1,784–1,901	.....	.....	.....	Several oil and gas wells.
Township	1,088–1,756	.....	.....	.....	80 wells; principally gas and oil.
Center[6].....	1,732	.....	.....	.....	Oil well.
Township	1,494–1,959	.....	.....	.....	59 wells; gas and oil.
City (one-half uth).[7]	1,454	.....	.....	.....	
Mills[8]	1,140	.....	.....	.....	Gas well.
r Burrell Town-	1,779	.....	.....	.....	
Township[9].....	765	.....	.....	.....	
tion (near)[10]...	1,900	.....	.....	.....	For oil or gas; unproductive.
'ownship	880–948	.....	.....	.....	3 wells.
.....	1,367	.....	.....	.....	
x Township[11]..	1,785–1,930	.....	.....	.....	Several oil and gas wells.
Township.....	1,248–2,027	.....	.....	.....	17 wells; gas and oil.
tation (1½ miles	2,135	.....	.....	.....	Gas well.
'ownship[13].....	1,183–1,418	.....	.....	.....	For oil; 3 wells.
.....	2,073–2,356	.....	.....	.....	2 wells.
wnship.....	1,164–1,482	.....	.....	.....	13 wells; principally oil.
[4].....	1,528–1,825	.....	.....	.....	Numerous oil and gas wells; some good producers.
(vicinity)[15]	1,400–1,631	.....	.....	.....	Numerous gas and oil wells.
[16]	1,707–1,711	.....	.....	.....	2 oil wells.
(north of)	1,738	.....	.....	.....	
(near)	1,780	8¼–6¼	.....	.....	Produces 11 barrels of oil a day; water-bearing strata at 170 and 600 feet.
:un District.....	1,380	.....	.....	.....	
vicinity)[17].....	1,445–1,577	.....	.....	.....	Gas wells.
tation[18]	3,055	.....	.....	.....	For oil or gas; abandoned
.....	1,930	.....	.....	.....	
ation[20].....	1,857	.....	.....	.....	Gas well.
rg (2 miles west)[21]	1,825	.....	.....	.....	For oil or gas.
Rock Township[22]	1,411	.....	.....	.....	Do.
.....	1,400–1,436	.....	.....	.....	For oil; unproductive.
.....	2,135	.....	.....	.....	
[24].....	1,822	.....	.....	.....	Gas well.
Township[25].....	1,735	.....	.....	.....	Oil well.
.....	1,080–2,527	.....	.....	.....	Many wells; oil and gas mostly.
ation[9]	912	.....	.....	.....	
(south of).....	1,956	.....	.....	.....	Gas well.
Township.....	400	.....	.....	.....	
.....	1,685	.....	.....	.....	For oil or gas; unsuccessful.
.....	1,030–2,680	.....	.....	.....	61 wells; principally gas; very little oil.
nty:					
Township.....	1,000	.....	.....	.....	
Mill[27]	653?	.....	.....	.....	Gas well.
'ree Borough[28]..	653	.....	.....	.....	Do.

[3]a, 2d Geol. Surv. Rept., Vol. I[4], p. 138.
141.
d. II, pp. 247–248.
6, part 2, pp. 718–719.
d. I[5], pp. 195–197.
6, part 2, pp. 716–717.
d. II, pp. 262–263.
. 270–271.
6, part 2, p. 720.
d. I[5], p. 210.
l. II, p. 271; Vol. I[5], pp. 197–198; Vol.
05.
6, part 2, pp. 717–718.
d. II, pp. 243–246.
6, part 2, pp. 713–716; Vol. I[5], pp. 203–
leol. Surv. Rept., vol. 1 (a), 1904, pp.

[15] Ibid., Vol. II, pp. 260–261, 283–296; W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 89–93.
[16] Ibid., Vol. I[5], pp. 194–195.
[17] Ibid., 1886, part 2, pp. 713–714; Vol. I[4], p. 138.
[18] Ibid., Vol. I[5], pp. 193–194.
[19] Ibid., p. 194.
[20] Ibid., Vol. II, p. 269.
[21] Ibid., p. 270.
[22] Ibid., Vol. QQ, p. 154.
[23] Ibid., Vol. I[4], pp. 143–144; Vol. I[3], 417–418.
[24] Ibid., Vol. I[3], p. 404.
[25] Ibid., Vol. II, pp. 268–269.
[26] Ibid., p. 716.
[27] Ibid., Vol. HH, pp. 176–180.
[28] Ibid., Vol. I[4], p. 146.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Cambria County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Cresson[1]	677				For oil.
Ebensburg	1,000	5¾	Many.	No flow.	
Johnstown[2]	2,856				For oil or gas; unprod tive.
Johnstown (4 miles west)[3]	2,500				Do.
Taylor Township	2,500				Unproductive.
Cameron County:					
Cameron station (one-half mile northeast).[4]	971				For oil.
Emporium[5]	1,410				Do.
Do	+400				
Emporium (4 miles northwest).[6]	1,607				For oil or gas; unpro tive.
Chester County:					
Parkesburg[7]	522				
Clarion County:					
Ashland Township[8]	1,128				Do.
Beaver Township[9]	1,001–1,200				For oil or gas.
Brush Run[10]	1,047–1,636				Oil and gas wells.
Clarion[11]	1,238–1,367				Several oil wells; o productive.
Clarion (near)	1,311				
Cooksburg (vicinity)[12]	843–2,050				For oil or gas; one ductive.
Crown Township	1,082				
Edenburg[13]	1,268				Good oil well.
Edenburg (1 mile southeast).[14]	1,046				
Elk Township[15]	977–1,450				Several oil or gas some unproductiv
Do	2,025				
Farmington Township	2,050				
Knox Township	1,207				
Madison Township	1,052–3,513				6 wells; some gas.
Mill Creek Township[16]	2,323				For oil or gas; unpr tive.
Do	1,367				
Millville[17]	2,280				Oil and gas well.
Piney Township	992				Oil.
	1,151				
Richland Township[18]	1,040–1,700				Several oil wells.
Salem Township[19]	1,198–1,200				Oil and gas wells.
Scotts Hill (near)	2,378				
Shippensville (1¼ miles south).[20]	2,025				For oil or gas; unpr tive.
Sligo[21]	1,151				Oil well.
Snydersburg[22]	1,207				Do.
Toby Township[23]	1,400	8			Do.
Turkey City (near)[24]	1,150				For oil or gas.
Township unknown	944				
Do	1,046–1,427				3 wells.
Do	1,636				
Do	2,130–2,280				2 wells.
Do	2,712				
Clearfield County:					
Clearfield (2 miles southwest).[25]	2,900				For oil or gas; unpr tive.
Dubois Station[26]	3,020				Do.
Dubois	3,006				For oil; unsuccessfu
Jordan Township	454–617				2 wells.
Clinton County:					
Crawford Township	458				Coal prospect; unsu ful.
Gallagher Township	3,525				
Hammersley Fork	−1,800				For oil.
Humes station (near)[27]	1,821				For oil or gas; unpr tive.
Lockhaven	3,525	6¼			For oil or gas; unsu ful.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. HH, p. 30.
[2] Ibid., Vol. I[5], pp. 169–170.
[3] Ibid., pp. 170–171.
[4] Ibid., Vol. RR, part 2, p. 23; Vol. G[4], p. 138.
[5] Ibid., Vol. G[4], p. 140.
[6] Ibid., p. 141.
[7] Record, Am. Phil. Soc., Proc., vol. 29, pp. 45–46.
[8] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 230.
[9] Ibid., Vol. II, pp. 228–229.
[10] Ibid., Vol. I[5], pp. 235–236.
[11] Ibid., pp. 157–159; Vol. III, pp. 413–414.
[12] Ibid., Vol. I[4], pp. 140–141.
[13] Ibid., pp. 139–140.
[14] Ibid., Vol. II, p. 229.
[15] Ibid., pp. 230–232; Vol. III, pp. 415–416.
[16] Ibid., Vol. II, pp. 232–234.
[17] Ibid., Vol. III, pp. 411–412.
[18] Ibid., Vol. II, pp. 226–227.
[19] Ibid., pp. 227–229.
[20] Ibid., Vol. I[3], pp. 414–415.
[21] Ibid., Vol. G[4], pp. 149–150; Vol. II, pp. 23
[22] Ibid., Vol. G[4], p. 149; Vol. I[4], p. 140.
[23] Ibid., Vol. I[3], pp. 412–413.
[24] Ibid., Vol. II, p. 227.
[25] Ibid., Vol. I[5], pp. 166–167.
[26] Ibid., pp. 165–166.
[27] Ibid., p. 197.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Clinton County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Renovo	4,000			−600	For oil; unsuccessful.
Do	3,460				Gas well.
Do	450–1,350				For oil or gas.
Columbia County:					
Montana	717–722	2			
Crawford County:					
Black Ash[1]	777				For oil or gas; abandoned.
Bloomfield Township[2]	590–1,000				Several oil wells.
Do	975				
Church Run[3]	415–700				Do.
Do	698–814				3 wells.
Concord Township[4]	845				Oil and gas well.
Conneautville (1 mile below).[5]	750				For oil or gas.
Dicksonburg	680?				Oil well.
Meadville[6]	900				Several oil wells in this vicinity.
Meadville (near)[7]	+475				
Oil Creek Township	3,500				For oil.
Do	550–971				3 wells.
Randolph (vicinity)[8]	565–950				Several oil wells.
Reeds Corners[9]	500				For oil or gas; abandoned.
Richmond Township	900				Oil and gas well.
South Shenango Township.[10]	1,065				Oil well.
Sparta Township[11]	465–1,507				Several oil and gas wells; some productive.
Spartansburg (2½ miles southeast).[12]	745				Gas well.
Spring Township	512				Do.
Titusville	600	10			
Titusville (near)[13]	3,553				For oil or gas.
Titusville (vicinity)[14]	400–806				Numerous oil and gas wells.
Troy Township	500–1,700				Several oil and gas wells; some unproductive.
Tryonville (vicinity)	600–1,000				Oil and gas wells.
Wayne Township[15]	600–1,100				Several oil and gas wells.
Woodcock Township	+600				For oil; unsuccessful.
Cumberland County:					
Carlisle (1½ miles southeast).	864	5–4½			
Carlisle (5 miles west)	420	5–4½			
Riverton (?)	485	5			
Dauphin County:					
Fort Hunter	2,675	6			Abandoned.
Harrisburg	2,800	6			For gas; abandoned.
Do	+400				2 wells.
Middletown[16]	2,440				Gas accompanied by strong flow of water.
Delaware County:					
Eagle Station	1,700		Few.		
Radnor Station	500	12			Abandoned.
Do	975	12–8	40–50	Pumped.	Probably surface water.
Elk County:					
Benezette[17]	721	3			For oil or gas; abandoned.
Dennis Run	424–632				13 wells.
Highland Township[18]	2,095–2,448				Many oil and gas wells; some abandoned.
Johnsonburg Station[19]	2,510				Large gas well.
Jones Township[20]	1,335–1,756				2 oil wells; 1 abandoned.
Maxwell Run	2,445				
Millstone Township	1,805–2,326				3 wells; some gas.
Ridgway[21]	1,820				Small gas well.
Do.[22]	772				
Ridgway Township[23]	1,678				For oil; unsuccessful.
Do	2,510				Gas well.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 186.
[2] Ibid., Vol. Q, pp. 224–226; Vol. II, pp. 273–274; Vol. I[4], p. 119.
[3] Ibid., Vol. II, pp. 66–69.
[4] Ibid., Vol. Q[4], p. 212.
[5] Ibid., pp. 216, 234–236.
[6] Pa. 2d Geol. Surv., Reports, Vol. Q[4], p. 175.
[7] Record, U. S. Geol. Surv. Monograph No. 41, pp. 457–458.
[8] Record, Pa. 2d Geol. Surv. Rept., Vol. Q[4], pp. 178–179.
[9] Ibid., p. 212.
[10] Ibid., p. 153.
[11] Ibid., Vol. I[5], pp. 186–187; Vol. Q[4], p. 227.
[12] Ibid., Vol. II, p. 69; Am. Philos. Soc. Proc., vol. 16, p. 493.
[13] Ibid., Vol. Q[4], p. 184; Vol. I[3], p. 154; Vol. I[4], p. 284.
[14] Ibid., Vol. I[4], pp. 118–119; Am. Philos. Soc. Proc., vol. 16, pp. 490–493.
[15] Ibid., Vol. Q[4], pp. 122–125.
[16] Record, U. S. Geol. Surv. Folio No. 82.
[17] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 133–134; Vol. RR., p. 248.
[18] Ibid., 1886, part 2, pp. 707–709; Vol. I[5], p. 155.
[19] Ibid., pp. 710–711.
[20] Ibid., Vol. I[4], pp. 127–128.
[21] Ibid., 1886, pt. 2, p. 711.
[22] Ibid., Vol. G[4], pp. 142–143.
[23] Ibid., pp. 129–131.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Elk County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
St. Marys (west of)[1]	2,010				Gas well.
Spring Creek Township[2]	880				For oil; unsuccessful.
Do	1,302 2,257 2,725				
Wilcox (4½ miles north)[3]	1,850				Small oil well.
Erie County:					
Amity Township	500–630				Several oil and gas well
Corry[4]	2,340				Gas and oil well.
Erie[5]	4,460				For oil or gas; abandoned
Do.[6]	1,250–1,418				Gas wells.
Do	470–800				Numerous gas and oil wells.
Fairview Township[7]	700–1,000				Several gas wells.
Girard Township[8]	980				For oil; unsuccessful.
Greenfield	780				Large gas well.
Leboeuf	780				Oil and gas well.
Springfield Township	400				For oil; unsuccessful.
Summit Township	400				Gas well.
Wayne Township	600				Gas and oil well.
Union City[9]	1,523				For oil or gas; unsuccessful.
Union Township	1,600				For oil; unsuccessful.
Waterford (2 miles west)	650				Oil and gas wells.
Fayette County:					
Belle Vernon[10]	2,005				Small gas well.
Brownsville[11]	+2,106				Gas well.
German Township[12]	1,196				Do.
Do	2,525				
Do[13]	2,907				
Haddenville[14]	1,712				Gas well; only small amount of gas.
Layton station[15]	2,100				For oil or gas; unproductive.
McClellandtown (1 mile southeast).[16]	1,196				Gas well.
Masontown[17]	2,525				Do.
Do.[18]	870–2,827				Many wells; gas, oil, and brine.
Menallen Township	1,712				
New Geneva (2½ miles southeast).[19]	2,050				
Oldframe (1 mile west)[19]	1,265				
Redstone Township	522				
Smithfield (1 mile north)[19]	1,858				Show of gas at bottom well.
South Union Township	744				
Tyrone Township	2,100				Unproductive.
Uniontown (3 miles northwest).[20]	2,001				Gas well.
Upper Middletown[21]	2,440				For oil or gas; unproductive.
Washington Township	2,005				Gas well.
Township unknown	2,106				Do.
Forest County:					
Barnet Township[22]	2,428				For oil or gas, unsuccessful.
Do	1,778–2,725				3 wells.
Barnet Township (40 rods from Clarion River).	2,726				
Brookston	2,200				For oil or gas; unsuccessful.
Cooksburg[23]	2,100–2,726				Do.
Delight (near)	1,225	8–5½			Gas well; hard water 80 feet.
Howe Township[24]	1,475–1,985				Several oil wells.
Do. (?)[25]	2,233				Gas well.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 131–132.
[2] Ibid., pp. 132–133.
[3] Ibid., Vol. G[4], pp. 143–146.
[4] Ibid., Vol. I[4], p. 228.
[5] Ibid., Vol. I[5], pp. 187–192.
[6] Ibid., Vol. I[4], pp. 122, 290.
[7] Ibid., Vol. Q[4], pp. 262–263.
[8] Ibid., p. 259.
[9] Ibid., Vol. I[4], p. 121.
[10] Ibid., 1886, part 2, pp. 778–779.
[11] Ibid., Vol. I[5], pp. 317–318.
[12] Ibid., pp. 321–322.
[13] *Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 115–116.*
[14] Record, U. S. Geol. Surv. Folio No. 82, p. 18.
[15] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 318–319.
[16] Record, U. S. Geol. Surv. Folio No. 82, pp. 18–19.
[17] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 322–323.
[18] U. S. Geol. Surv. Folio No. 82, 1902, p. 20.
[19] Record, ibid., p. 19.
[20] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 320–321.
[21] Ibid., p. 319.
[22] Ibid., p. 154.
[23] Ibid., pp. 159–161.
[24] Ibid., Vol. I[4], pp. 79–81; 1886, part 2, p. 700.
[25] Ibid., 1886, part 2, pp. 700–701.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Forest County—Continued.					
Jenks Township[1]	400–1,003				Several gas or oil wells; unproductive.
Do.[2]	1,310–2,505				Several wells; mainly unproductive.
Do	2,630				
Kingsley Township[3]	2,200				For oil or gas; unproductive.
Marienville (near)[4]	1,305				
Neilltown (vicinity)[5]	780–995				Numerous oil and gas wells; some unproductive.
Tionesta (near)[6]	437				Oil and gas well.
Tionesta Township[7]	554–2,177				For oil or gas; unproductive.
Do	2,055–2,425				3 wells.
Franklin County:					
Chambersburg	+400				
Chambersburg (2 miles west).	600	6		−17	Water at 420 feet.
Greene County:					
Aleppo Township[8]	3,030–3,343				6 wells; gas and oil.
Blacksville[9]	500?				For oil.
Carmichaels (vicinity)[10]	2,432				For oil or gas.
Center Township	805				Gas well.
Do	2,980				Oil well.
Do	3,046–3,267				2 gas wells.
Cumberland Township	2,432				
Deep Valley (near)[11]	3,398 3,478				2 wells.
Dunkard Township	798–2,620				Many oil and gas wells; some unproductive.
Franklin Township	400–888				8 wells; 5 gas, 2 unproductive.
Do	1,931–3,353				50 wells; principally gas.
Greene Township	731				Oil and gas well.
Do	2,165				
Greensboro[12]	668				Oil well.
Greensburg (4 miles southwest).[13]	769				Do.
Higbee (near)	3,337	10–5			For oil; unsuccessful; Pittsburg coal at 1,022 feet; brine at 1,862 feet.
Do	3,076	13–5			For oil; Pittsburg coal at 927 feet.
Jackson Township	3,125–3,211				3 wells; unproductive.
Jefferson[14]	2,658				
Jefferson Township	2,050				Gas well.
Do	2,920–3,182				4 wells; 3 gas.
Jollytown (2 miles northeast).[15]	3,278				
Jollytown (3 miles west).[16]	3,477				
Mount Morris (near)[16]	1,772				Oil well.
Do.[17]	1,905				For oil.
Morgan Township	750				Gas well.
Do	2,606–3,278				11 wells; mostly gas.
Morris Township	825–980				3 wells; 2 oil, 1 unproductive.
Do	1,010–3,290				22 wells; oil and gas, some unproductive.
Do	2,965	13–6			Gas well; Pittsburg coal at 935 feet, gas at 2,940 feet
New Freeport (3¼ miles southwest).[18]	3,466				
Nineveh (vicinity)[19]	2,970–3,221				Several wells.
Perry Township	1,730–3,261				6 wells; gas and oil.
Richhill Township	2,424–3,413				9 wells; gas and oil, 1 unproductive.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 81–83.
[2] Ibid., pp. 83–86; 1886, part 2, pp. 702–705.
[3] Ibid., 1886, part 2, pp. 703–704.
[4] Ibid., Vol. G[4], pp. 146–147.
[5] Ibid., Vol. I[4], pp. 69–77.
[6] Record, Am. Philos. Soc. Proc., vol. 16, p. 488.
[7] Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 77–79; 1886, part 2, pp. 705–707.
[8] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, p. 129.
[9] Record, Pa. 2d Geol. Surv. Rept., Vol. K, pp. 108–109.
[10] Ibid., Vol. I[5], pp. 315–316.
[11] Record, W. Va. *Geol. Surv. Rept., vol. 1* (a), 1904, *p. 128–129.*
[12] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, part 2, p. 774.
[13] Ibid., Vol. I[4], p. 145.
[14] Ibid., Vol. I[5], pp. 314–315.
[15] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, p. 127.
[16] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 316–317.
[17] Record, Bull. Geol. Soc. Am., vol. 3, p. 189; U. S. Geol. Surv. Folio No. 82, p. 19.
[18] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 129–130.
[19] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 308–312; W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 130–131.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Greene County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Ryerson station (north of).[1]	2,716				For oil or gas.
Springfield Township	3,146				Gas.
Spring Hill Township	3,434	10-5			Gas at 3,369 feet; pressure 900 pounds.
Do	3,234	10-5			Gas at 3,183 and 3,228 feet.
Washington Township	962				Oil.
Do	2,871-3,441	?			7 wells; 1 oil, 3 gas, 3 unproductive.
Wayne Township	605-852				8 wells; 1 gas, 4 unproductive.
Do	2,020-3,780				18 wells; principally gas.
Waynesburg[2]	2,745				Oil well; abandoned.
Waynesburg (2 miles northeast).[3]	3,260				
Waynesburg (3 miles northeast).[3]	3,004				
Waynesburg (4 miles southeast).[4]	2,965	4			
Waynesburg (several miles southwest).[5]	3,008 3,780 3,298				3 wells.
Waynesburg (vicinity)[6]	2,675-2,900				2 oil and gas wells; 1 unproductive.
Whiteley Township	2,922 3,299				12 wells; mostly gas; 2 unproductive.
Willow Tree[7]	2,165				For oil or gas; abandoned.
Township unknown	835				Oil well.
Do	2,585				
Do	3,080-3,272				5 wells; 1 gas, 3 unproductive.
Huntingdon County:					
Huntingdon	400				Several wells.
Hyner Station (near)[8]	1,187				For oil.
Indiana County:					
Blacklick (vicinity)[9]	1,728				For oil or gas; abandoned
Burrell Township	2,160-2,357				2 wells; 1 dry.
Center Township	2,125				
Conemaugh Township	1,545-1,734				2 gas wells.
Indiana Township	2,054				Gas well.
North Mahoning Township.	2,615?				Do.
Punxsutawney (vicinity).[10]	2,745				Gas well.
Saltsburg (near)[11]	2,014				For oil or gas; unproductive.
Saltsburg district	2,216				Gas well.
Washington Township	1,100-1,620				8 wells; 7 gas, 1 unproductive.
West Mahoning Township.	1,605				Gas.
White Township	433				Coal.
Do	3,246				
Township unknown	3,220				
Do	414				Do.
Do	1,190-1,200				3 wells; 1 gas.
Do	1,839-1,930				2 wells; 1 unproductive.
Jefferson County:					
Barnett Township	1,845				Brine.
Do	2,170				
Beaver Township	2,705-2,716				2 wells.
Brookville[12]	3,100				For oil or gas; unproductive.
Do.[13]	1,700				Gas well.
Brookville Borough[14]	2,430				Do.
Eldred Township	2,850				
Falls Creek station (near).[15]	3,040				Do.
Heath Township	1,870-2,955				2 wells.
Horatio	543			10	
Knox Township[16]	1,608-2,000				Moderate gas wells.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 312-313.
[2] Ibid., 1886, part 2, pp. 772-773.
[3] Record W. Va. Geol. Surv. Rept., vol. 1 (a), 1904 p. 121.
[4] Ibid., p. 122.
[5] Ibid., pp. 122-126.
[6] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 312.
[7] Ibid., p. 316, U. S. Geol. Surv. Folio No. 82, p. 20.
[8] Ibid., Vol. G[4], pp. 131-134.
[9] Ibid., Vol. I[5], p. 168.
[10] Ibid., 1886, part 2, pp. 776-777.
[11] Ibid., Vol. I[5], pp. 167-168.
[12] Ibid., pp. 163-164.
[13] Ibid., Vol. I[4], p. 139.
[14] Ibid., 1886, part 2, p. 778.
[15] Ibid., Vol. I[5], p. 164.
[16] Ibid., pp. 162-163.

PENNSYLVANIA—Continued.

cation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
unty—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
ownship	1,734–2,720				3 wells; 1 gas.
vnship	2,205				
vnship	1,951				
ownship	1,105				Unproductive.
ownship	2,359				
ton Township	3,040				Gas.
p unknown	1,734				Dry (?).
	2,015				
	2,985				Gas.
	3,100–3,200				2 wells; 1 dry.
ı County:					
	780	6	25		
ı (1 mile south-	2,050	6			Abandoned.
ı (2 miles north-	+700	6	30	Flows.	
ı (3 miles west)	±1,000	6	40		
ı (6 miles north-	2,200	8–6			
	2,380				Water in small quantity.
ounty:					
le[1]	2,700	5¼			For oil or gas; unproductive.
le (vicinity)	1,912				Gas and oil well.
	700–900				Several wells.
ssing	3,830	8–6¼			Oil and water at 240 feet; gas at 500, 575, and 825 feet; abandoned, with two sets of tools in well.
Township[2]	790				For oil; unsuccessful.
nty:					
ı	482–690	2			Coal prospects.
ı (Diamond Wa	800	8		Flow.	2 wells.
).					
	464–511	2			2 wells.
arre	536	2			
	466				For water; unsuccessful.
nty:					
l[3]	1,085				For oil.
l (vicinity)[4]	1,010–1,719				Numerous oil and gas wells.
(1 mile from)[5]	1,532–1,601				Gas wells.
(near)[6]	1,404				For oil or gas.
n Township[7]	2,011				Oil well.
Township[8]	2,315–2,400				Several oil wells; some unproductive.
	1,613–1,768				Several oil wells; one abandoned.
e Township[10]	2,111–2,490				Several oil and gas wells.
ne (3 miles	1,130				Oil well.
ollow[11]	1,390				For oil or gas; unproductive.
l (near)	1,040				Oil well.
station[12]	2,000				For oil or gas; abandoned.
station (near)[13]	2,263				Dry hole.
	2,000				
Township[15]	2,004				For oil or gas.
	1,850				For oil and gas.
	1,785				For oil or gas; abandoned.
	2,043				Excellent gas well.
	1,802				Good gas well.
	2,000–2,380				Several oil and gas wells.
	1,943				
rt (west of)[21]	2,004				For oil; abandoned.
rt (vicinity)[22]	1,293–1,900				Several oil and gas wells; small production.
n[23]	970				Oil well.
lley[24]	1,035–1,919				Several oil and gas wells.

Pa. 2d Geol. Surv. Rept., Vol. G⁴, pp. II, pp. 275–276.
d. QQ, p. 89.
l. I⁴, pp. 97–103.
89; Vol. R, pp. 287–290.
. 259–261.
90.
d. R, pp. 266–267.
d. I⁵, pp. 151–152.
d. R, pp. 179–182. Vol. I⁴, pp. 111–113.
d. I⁵, pp. 152–153.
d. I⁴, p. 97.
, Ibid., Vol. R, p. 92.

[13] Ibid., pp. 243–245.
[14] Ibid., pp. 245–248.
[15] Record, ibid., Vol I⁴, pp. 106–108.
[16] Ibid., pp. 108–111.
[17] Ibid., pp. 104–106.
[18] Ibid., 1886, pt. 2, pp. 695–696.
[19] Ibid., p. 698.
[20] Ibid., pp. 696–698, Vol. I⁴, p. 117.
[21] Ibid., Vol. R, pp. 271–272.
[22] Ibid., pp. 272–276.
[23] Ibid., Vol. I⁴, p. 91.
[24] Ibid., pp. 87–92.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Mercer County:					
Jamestown [1]	1,063				Oil and gas well.
Mercer (near) [2]	1,702				Gas well.
Middlesex (near) [3]	2,030				For oil or gas; un tive.
Middlesex, West (1 mile south).[4]	3,484				Do.
Sharon (1¼ miles above)[5]	1,600				For gas or oil.
Stoneboro (near)[6]	950				Oil well.
Mifflin County:					
Newton Hamilton	800				Not in operation.
Montgomery County:					
Ambler	500	6	250		3 wells; pumped.
Bryn Mawr	55)	8	83	−310	
Do	600	6	120		
Bryn Mawr (college)	862				
Bryn Mawr (hotel)	404				
Fitzwatertown	560				For oil; unsuccess
Lansdale	611		200	No flow.	
Pennsburg	1,000				
Port Kennedy	581	8	130	No flow.	Water strata at and 500 feet.
Northampton County:					
Easton	500		105	− 43	
Mount Carmel	900	2			
Philadelphia County:					
Frankford Junction	500	8			Pumped.
Philadelphia (Melrose)	553	10–8	150	− 6	
Ambler Works	500	6	250		
Morocco Works	500	6	500		
N. & G. N. Taylor	670	12	250		
League Island [7]	906			−28	Gneiss below 260 f ter at 536 feet.
Hog Island	456				
Brown and 24th sts	495	6	60		
Mount Vernon and 13th streets.	3,031	8	2,600		
Callow Hill and 7th street).	452	8	150		
Crown and Willow street.	1,000	10	100		
Market and 15th sts	500	8	100		
108 South Broad st	484	8	60		
Broad street below Locust.	525	8	110		
Amholt & Schaefer Brewing Co.	1,500		50		
Boiler Works	500				
Potter County:					
Abbot Township	2,100				Oil boring; unsuc
Do.[8]	2,029				Small gas well.
Coudersport [9]	2,100				Small gas well.
Harrison Township [10]	1,995				
Hebron [11]	1,286				For oil.
Pike Township [12]	1,835				For oil or gas; un tive.
Do. [13]	1,500				For oil or gas; aba
West Branch Township [14]	1,750–2,750				For oil; unsuccess
Schuylkill County:					
Pinegrove	450	8	Many.	No flow.	
Ashland (vicinity)	1,830	2	139	Flows.	Temp., 54°.
Delano	515	2			Coal prospect.
East Brookside	585	8			Oil well.
Mahanoy City (near)	1,130	2	Many.	Flows.	Temp., 51°.
Shenandoah (near)	538	8			Oil well.
Towet City	418				
Tremont		8			Do.
Somerset County:					
Elklick	+1,500				
Do	2,900				For oil.
Salisbury Basin [15]	678				
Wellersburg	1,207				Good water.
Township unknown	634				

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. II, pp. 274–275.
[2] Ibid., p. 275.
[3] Ibid., Vol. I[5], pp. 229–230.
[4] Ibid., pp. 230–231.
[5] Ibid., Vol. I[3], p. 419.
[6] Ibid., p. 121.
[7] Record, N. J. Geol. Surv. Rept., 1900, pp. 137–142.
[8] Record, Pa. 2d Geol. Surv. Ann. Rep pp. 85–86.
[9] Ibid., 1886, part 2, pp. 775–776.
[10] Ibid., Vol. G[3], pp. 80–81.
[11] Ibid., Vol. G[3], p. 79.
[12] Ibid., Vol. I[5], pp. 148–149.
[13] Ibid., pp. 149–150.
[14] Ibid., 1885, pp. 86–91.
[15] Ibid., Vol. I[4], pp. 146–147.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Tioga County:					
Elkland					For oil or gas.
Gaines [1]	1,845				For oil or gas; abandoned.
Gaines oil field [2]	565–1,320				90 wells for oil.
Wellsboro					
Union County:					
Foresthill	480			Flows.	Sulphur water.
Venango County:					
Alleghany Township [3]	850				For oil; unproductive.
Do	619–925				3 wells.
Black's siding [4]	1,650				For oil or gas; unproductive.
Clinton Township [5]	836–1,266				Several oil wells; mainly productive.
Cornplanter Township [6]	451–924				For oil or gas.
Cornplanter Township(?) =(bluff between Petroleum Center and Pioneer).	780–835				4 wells.
Cornplanter Township	551–802				43 wells.
Do	1,002–1,018				3 wells.
Cranberry Township	450–600				Several wells.
Do. [7]	600–1,506				Numerous oil and gas wells; mainly productive.
Emelton (vicinity) [8]	720–1,000				Numerous oil wells; mainly productive.
Franklin (one-half mile northeast). [9]	490			Flows.	Good oil well.
Franklin (8 miles south) [10]	3,880				For oil or gas; unproductive.
Jackson Township [11]	688				Oil well.
Do	583–688				3 wells.
Mineral Township	893–986				5 wells.
Do	1,015–1,350				3 wells.
Oakland Township [12]	640				
Oil City [13]	1,070				
Do. [14]	540–818				Several oil wells.
Oil Creek Township [15]	902–1,000				Do.
Do	415–936				22 wells.
Petroleum Center [16]	500–900				Numerous oil wells; mainly productive.
Do	1,010				
Pinegrove Township [17]	1,869–2,060				Several oil wells.
Do. [18]	912–1,070				For oil.
Pioneer (vicinity) [19]	437–980				Numerous oil wells; large production.
Pithole City [20]	747				For oil or gas; unproductive.
Pleasantville (2¼ miles northwest). [21]	415				Oil well.
Pleasantville (4½ miles southeast). [22]	1,000				Gas and oil well.
Pleasantville (2 miles northeast). [23]	885				Do.
Pleasantville Borough [24]	693–1,044				Numerous oil and gas wells.
Pleasantville	633–955				66 wells.
Do	1,020–1,050				2 wells.
Pleasantville Corners	840–870				Do.
Pleasantville (?)	607–620				Do.
Plumer (?)	930				

[1] Record, Pa. 2d Geol. Surv. Ann. Rept., Vol. I[5], pp. 147–148; U. S. Geol. Surv., 22d Ann. Rept., 1900–1901, part 3, pp. 583–584.
[2] U. S. Geol. Surv., 22d Ann. Rept., 1900–1901, pp. 585–591.
[3] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 58–59.
[4] Ibid., Vol. I[5], pp. 184–185.
[5] Ibid., Vol. II, pp. 219–222.
[6] Ibid., Vol. I[4], pp. 59–61.
[7] Ibid., Vol. II, pp. 203–207, 210–214; Vol. I[4], pp. 62–63.
[8] Ibid., Vol. II, pp. 222–225.
[9] Ibid., Vol. I[4], p. 65.
[10] Ibid., Vol. I[5], pp. 185–186; W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 86–87.
[11] Ibid., Vol. II, p. 201.
[12] Ibid., p. 202.
[13] Ibid., Vol. III, p. 416.
[14] Record, Am. Philos. Soc. Proc., vol. 16, pp. 482–487; Pa. 2d Geol. Surv. Rept., Vol. II, pp. 204–205.
[15] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 53–54.
[16] Record, Am. Philos. Soc. Proc., vol. 16, pp. 470–477.
[17] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 184.
[18] Ibid., Vol. I[4], p. 64.
[19] Ibid., Vol. II, pp. 43–64; Am. Philos. Soc. Proc., vol. 16, pp. 468–471.
[20] Ibid., Vol. I[5], p. 179.
[21] Ibid., p. 175.
[22] Record, Am. Philos. Soc. Proc., vol. 16, p. 497.
[23] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 54–55.
[24] Ibid., Vol. II, pp. 9–34; Vol. III, p. 420; Vol. I[4], p. 55; Am. Philos. Soc. Proc., vol. 16, pp. 435–460.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Venango County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Plumer (1 mile south)[1]	464				
President (near)[2]	1,280				For oil or gas; abandoned.
Raymilton[3]	893–1,410				Numerous oil or gas wells.
Raymilton (near)[4]	845–1,410				Several oil or gas wells.
Reno[5]	570–590				Several oil wells.
Do.	1,090				For oil; unproductive.
Richland Township	705–970				4 wells.
Rockland station[6]	701				For oil; abandoned.
Rockland Township[7]	600–1,100				Numerous oil wells.
Do.	1,094				
Do.	1,650				
Rouseville (vicinity)[8]	450–800				Do.
Salem (vicinity)[9]	962–1,200				Several oil or gas wells.
Salina (?)	1,020				
Sandy Creek Township[10]	792				Small oil well.
Do.	1,410				
Scrubgrass Township	720–740				4 wells.
Do.	1,100				
Shamburg[11]	547–972				Numerous oil wells.
Sugar Creek Township[12]	568–606				2 oil wells; 1 abandoned.
Sulphur Run[13]	926–1,350				2 oil wells.
Titusville[14]	538–966				Numerous oil and gas wells.
Victory Township	3,880				
Township unknown	448–980				46 wells.
Do.	1,016				
Warren County:					
Cherry Grove Township[15]	1,548–2,004				Several oil and gas wells; some unproductive.
Colorado district	551–822				17 wells.
Corydon Township	720				For oil.
Deerfield Township	546–690				2 wells.
Do.	484–537	8–5¾			Several wells; for oil.
Dennis Run[16]	426–632				Several oil and gas wells.
Eldred Township[17]	415–481				Oil and gas wells.
Do.	568–914				2 wells.
Do.	420–1,250	8–5¾			Many wells; for oil.
Elk Township[18]	1,500				For oil; abandoned.
Elrod Township[19]	588–914				For oil or gas.
Enterprise[20]	474–487				Several oil wells.
Enterprise (vicinity)[21]	462–800				Do.
Fagundas Township	618–760				4 wells.
Do.	803				
Gilson Run	541				
Grand Valley (4 miles south).	789	8¼–5¾			For oil; fresh water at 55 feet.
Kinzua Township[22]	1,048–2,285				Several oil wells; mainly unproductive.
Limestone Township	431–743				8 wells.
Do.	1,005				
Lottsville[23]	960–1,515				2 oil or gas wells; abandoned.
Neilltown Township (?)	1,000				
North Warren (near)[24]	475–965				Numerous gas and oil wells; some unproductive.
Do.[25]	1,200–1,400				Several oil and gas wells; unproductive.
Do.[26]	1,835				For oil; abandoned.
Pinegrove Township[27]	750–1,830				Several oil and gas wells; small production.
Pittsfield (township)[28]	747				For oil or gas; unproductive.

[1] Record Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 180.
[2] Ibid., pp. 180–181.
[3] Ibid., Vol. I[5], pp. 181–183; Vol. I[4], p. 68; Vol. III, pp. 419–420.
[4] Ibid., Vol. I[4], pp. 68–69.
[5] Ibid., Vol. II, pp. 208–210.
[6] Ibid., Vol. II, p. 207.
[7] Ibid., pp. 215–218.
[8] Ibid., Amer. Philos. Soc. Proc., vol. 16, pp. 477–486.
[9] Record, Pa. 2d Geol. Surv. Rept., Vol. II, pp. 205–206.
[10] Ibid., p. 201.
[11] Ibid., pp. 34–42; Am. Philos. Soc. Proc., vol. 16, pp. 460–468.
[12] Ibid., Vol. II, pp. 200–201.
[13] Ibid., Vol. I[5], pp. 182–183.
[14] Ibid., Vol. I[4], p. 56.
[15] Ibid., pp. 26–27. 375–376.
[16] Record, Am. Philos. Soc. Proc., vol. 16, pp. 367–370.
[17] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 52–53.
[18] Ibid., p. 30.
[19] Ibid., Vol. II, pp. 195–196.
[20] Ibid., pp. 65–66.
[21] Record, Am. Philos. Soc. Proc., vol. 16, pp. 367–369.
[22] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 27–29.
[23] Ibid., Vol, I[5], pp. 232–233.
[24] Ibid., Vol. I[4], pp. 10–15.
[25] Ibid., pp. 11–13.
[26] Ibid., p. 12.
[27] Ibid., Vol. I[4], pp. 16–18.
[28] Ibid., Vol. II, p. 196.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Warren County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Pittsfield (township)[1]	1,500				For oil or gas; unsuccessful.
Pleasant Township[2]	1,586				For oil or gas; unproductive.
Do.[3]	818–900				Several small oil wells.
Sheffield (vicinity)[4]	1,645				Good gas well.
Do.[5]	1,565?				For oil or gas; unsuccessful.
Do	825				For oil or gas; abandoned.
Do.[6]	961–1,200				For oil or gas.
Sheffield Township[7]	1,435–2,016				Numerous oil and gas wells.
Spring Creek Township[8]	600–1,061				Several oil and gas wells; small production.
Do	484	8–5¾			For oil; fresh water flowed 10 gallons a minute at 198 feet; oil and gas strata at 224 and 463 feet; abandoned.
Southwest Township[9]	500–1,550				Numerous oil and gas wells.
Stoneham (vicinity)[10]	1,025–1,600				Several oil and gas wells; mostly productive.
Tidioute (vicinity)[11]	403–715				Numerous oil and gas wells; none large producers, and many abandoned.
Do	803				
Triumph[12]	+472				For oil; unsuccessful.
Triumph (vicinity)[13]	739–815				Several oil wells.
Triumph Township[14]	2,464–2,700				For oil or gas; unsuccessful.
Do.[15]	805–908				Numerous oil and gas wells.
Do	543–961				13 wells.
Warren (near)[16]	531–1,065				Numerous oil and gas wells; some good producers.
Warren Township (?)	2,016				
Watson Township[17]	1,986				For oil or gas; unproductive.
Wrightsville (1 mile northeast).[18]	1,200				Abandoned as dry hole.
Near Warren-McKean County line.	2,254				
Washington County:					
Allen Township[19]	2,060				Gas well.
Amwell Township[20]	2,385				For oil or gas; unproductive.
Do	2,390				Gas.
Do	460–602				3 wells.
Beallsville (one-half mile east).[21]	3,200	10–4			
Beallsville (10 miles west).[22]	2,774				
Buffalo Township	510				
Do	2,350–2,760				21 wells; some oil and gas.
Cannonsburg (vicinity).[23]	1,763–2,502				Numerous oil and gas wells; some unproductive.
Canton Township[24]	2,727				For oil or gas.
Do	2,068				Gas well.
Do	1,977				Do.
Carroll Township	2,152 2,218				2 gas wells.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. II, p. 197.
[2] Ibid., Vol. I[5], p. 174.
[3] Ibid., Vol. I[4], p. 19.
[4] Ibid., pp. 23, 379–380.
[5] Ibid., pp. 24, 380–381.
[6] Ibid., Vol. II, pp. 194–195.
[7] Ibid., pp. 193–194; Vol. I[4], pp. 24–26; Vol. I[5], pp. 174–175; 1886, part 2, pp. 698–700.
[8] Ibid., Vol. I[4], pp. 252–263.
[9] Ibid., pp. 49–52; Vol. I[5], p. 855; Am. Philos. Soc. Trans., vol. 16, pp. 346–367.
[10] Ibid., pp. 20–23.
[11] Ibid., pp. 31–48; Am. Philos. Soc. Proc., vol. 16, pp. 372–374.
[12] Record, Am. Philos. Soc. Proc., vol. 16, p. 494.
[13] Ibid., pp. 370–372.
[14] Record, Pa. 2d Geol. Surv. Rept., Vol. I[4], pp. 280–283.
[15] Ibid., Vol. I[5], pp. 173–174; Vol. I[3], pp. 283–286.
[16] Ibid., Vol. I[4], pp. 1–9.
[17] Ibid., p. 20.
[18] Ibid., p. 236.
[19] Ibid., Vol. I[5], pp. 301–302.
[20] Ibid., pp. 307–308.
[21] Record., etc., W. Va. Geol. Surv. Rept., vol. 1(a), 1904, pp. 116–119.
[22] Ibid., p. 121.
[23] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 281–297.
[24] Ibid., pp. 279–280.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Washington County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Cecil Township	2,247				Brine.
Charleroi (southwest of)	2,090 to +2,165				Several wells; for oil or gas.
Cross Creek Township	4,303				
Donegal Township	3,200				Unproductive.
East Bethlehem Township.[1]	604				Salt well; abandoned.
East Bethlehem Township (and vicinity).	2,017–3,180				14 wells; principally gas
East Pike Run Township[2]	1,950				Gas well.
Fallowfield Township (southeast corner).[3]	1,950				Do.
Franklin Township[4]	2,608				For oil or gas; abandoned.
Good Intent (2½ miles southwest).[5]	2,720				For oil or gas; unproductive.
Hickory					Gas well.
Hickory (2½ miles southwest).[6]	2,245				Large gas well.
Hickory (2 miles southeast).[7]	2,205				Large flow of gas.
Hickory (vicinity)[8]	700–1,151				Several large gas wells.
Hopewell Township	3,455				Unproductive.
Little Washington					2 gas wells.
Lock No. 3	2,495				Gas well.
McDonald[9]	2,342				Do.
Monongahela[10]	2,152–2,218				Gas wells.
Morris Township	506–919				5 wells; 1 gas, 2 oil.
Do	2,822				
Mount Pleasant Township.	700				Gas well.
Do	1,060–2,245				4 wells; 1 gas.
North Strabane Township.	1,800				Small gas well.
South Strabane Township.[11]	2,410–2,503				Gas wells.
Taylorstown[12]	2,350–2,760				Several gas and oil wells.
Thomas (near)	2,275	13–6½			For oil; water at 80 and 1,082 feet; gas at 1,285 feet.
Venice (1 mile northwest).[13]	2,247	7¾–5½			For oil or gas; unsuccessful.
Washington[14]	2,285–2,599				Several oil and gas wells.
Washington (near)[15]	1,977–2,420				Do.
West Alexander (3 miles west).[16]	3,200				For oil or gas; unproductive.
West Amity Station (near).[17]	+2,390				Gas well.
West Bethlehem Township.	490				
Do	2,685 / 2,967				2 gas wells.
Do	3,013				
West Finley Township	2,720				Unproductive.
West Middletown[18]	3,455				For oil or gas; abandoned.
West Pike Run Township.	2,806				
Woodrow (near)[19]	+4,303				Gas well.
Township unknown	1,763–1,998				5 wells; 3 gas.
Do	2,054–2,458				13 wells; 3 gas, 1 oil.
Do	2,502–2,900				3 wells; 2 dry.
Wayne County:					
Forest City					Coal prospect.
Honesdale (5 miles from)	2,500				2 oil wells; abandoned.
Honesdale (6 miles north).[20]	1,505				For oil.
Westmoreland County:					
Allegheny Township[21]	1,250–2,847				For oil or gas; mostly unproductive.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. K, pp. 178–179.
[2] Ibid., Vol. I^5, pp. 302–303.
[3] Record, U. S. Geol. Surv. Folio 94, pp. 17–18.
[4] Record, Pa. 2d Geol. Surv. Rept., Vol. I^5, p. 279.
[5] Ibid., pp. 305–306.
[6] Ibid., 1886, part 2, pp. 754–755.
[7] Ibid., pp. 769–772.
[8] Ibid., pp. 758–760; Am. Philos. Soc. Proc., vol. 16, p. 489.
[9] Record, W. Va. Geol. Surv. Rept., vol. 1, 1889, pp. 214–230.
[10] Pa. 2d Geol. Surv. Rept., Vol. I^5, p. 301.
[11] Record, ibid., p. 280.
[12] Ibid., pp. 298–299.
[13] Ibid., 1886, part 2, pp. 759–760.
[14] Ibid., pp. 764–767.
[15] Ibid., pp. 760–769; W. Va. Geol. Surv. Rept., vol. 1(a), 1904, p. 120.
[16] Ibid., Vol. I^5, pp. 304–315.
[17] Ibid., p. 307.
[18] Ibid., 1886, part 2, pp. 756–758.
[19] Ibid., pp. 755–756.
[20] Ibid., Vol. G^6, pp. 91–93.
[21] Ibid., Vol. I^5, pp. 211–215; Vol. II, pp. 277–278.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Westmoreland County—Con.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Bell Township	1,878				Unproductive.
Do	2,392				
Do	2,575				Gas.
Blairsville[1]	2,060				For oil or gas; abandoned.
Burrell Township[2]	2,500				
Do.[3]	1,850				Do.
Do	2,060				Gas.
Carpenters station (near).[4]	1,541				For oil or gas.
Cookville (north and west).	1,960–2,170				Several wells; for oil or gas.
Derry Township	450–521				2 wells; brine.
Do	1,015 2,502				2 wells.
East Huntingdon Township.	2,070				Unproductive.
Franklin Township	1,312–1,450				10 gas wells.
Gibsonton (three-fourths mile north).[5]	2,633				Gas well.
Hempfield Township[6]	1,255				Do.
Irwin	4,380				
Do.[7]	2,340				For oil or gas; unproductive.
Latrobe[8]	1,980				For oil or gas.
Lower Burrell Township.	1,565–2,896				10 wells; 8 gas.
Loyalhanna Township	1,755				Unproductive.
Do	2,180–2,216				2 wells; 1 gas.
Mount Pleasant Township.	844				Gas well.
Murrysville[9]	1,337–1,440				Numerous oil and gas wells.
Murrysville (vicinity)[10]	1,312–1,465				Large oil field.
North Huntingdon Township.	2,340				Unproductive.
North Washington Township.	1,608–1,791				3 gas wells.
Oakland Cross Roads	1,742–1,787				2 wells.
Pennsylvania Township.[11]	2,495				Large gas well.
Do.[12]	1,580–1,690				Several large gas wells.
Pleasant Unity (2¼ miles northwest).[13]	650				For oil or gas; unproductive.
Reagantown (south of)[14]	2,070				Do.
Rostraver Township	2,662–2,803				
Sewickley Township	1,769–3,150				2 unproductive wells.
Webster Township (northeast, east, and southeast).	1,935–2,250				Many wells; for oil and gas.
Tarentum (1¼ miles southeast).					For oil or gas; abandoned.
Unity Township	650				Unproductive.
Upper Burrell Township.	2,302–2,500				3 wells; 2 gas.
Waltz Mill (near)[15]	1,769–3,151				2 borings for oil or gas; unproductive.
Washington Township[16]	1,301–1,638				Gas wells.
Do	1,501–2,250				11 wells; 8 gas.
Township unknown	755				
Do	2,663				
Wyoming County:					
Lovelton (near)					Deep well.
York County:					
Manchester[17]	1,520				For oil or gas.
Miscellaneous:					
Allegheny River	403				
Boydstown Township	1,210				
Eulalia Township	2,100				
Grimes Township	1,345				
Hooks Run	1,426				
West Hickory Creek	400–632				2 wells.
Do	2,525–2,900				5 wells; 1 gas.
Do	3,020				
Do	760–869				3 wells; 2 gas.

[1] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 224–225.
[2] Ibid., pp. 212–213.
[3] Ibid., 1886, part 2, pp. 686–687.
[4] Ibid., pp. 725–726.
[5] Record, U. S. Geol. Surv. Folio No. 94, p. 18.
[6] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 223.
[7] Ibid., pp. 221–222.
[8] Ibid., pp. 223–224.
[9] Ibid., pp. 215–218.
[10] Ibid., 1886, part 2, pp. 673–674, 721–724.
[11] Ibid., Vol. I[5], pp. 219–220.
[12] Ibid., pp. 218–219; 1886, part 2, pp. 724–725
[13] Ibid., Vol. II, pp. 280–281.
[14] Ibid., Vol. I[5], pp. 227–228.
[15] Ibid., pp. 225–227.
[16] Ibid., 1886, part 2, pp. 726–730.
[17] Ibid., Vol. II, pp. 278–279.

PENNSYLVANIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Miscellaneous—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
West Hickory Creek	1,040-1,460				14 wells; 6 gas.
Do	1,505-1,980				19 wells; 6 gas; 1 oil.
Do	2,000-2,405				7 wells; 1 gas; 1 oil.
Do	2,665-3,375				2 wells; 1 gas; 1 dry.
Do	1,325-1,475				3 wells; 2 gas.
Do	1,504-1,635				8 wells; 4 gas.

PUBLICATIONS RELATING TO DEEP BORINGS IN PENNSYLVANIA.

Oil well records, selected from the collections of Mr. J. F. Carll, by J. P. Lesley: American Philosophical Society Proceedings, volume 16, pages 346–380, Philadelphia, 1877.

On the first systematic collection and discussion of the Venango County oil wells of western Pennsylvania, by E. S. Nettleton, prepared for publication by J. F. Carll: American Philosophical Society Proceedings, Nos. 97–99, for 1876–1877, volume 16, pages 429–495, Philadelphia, 1877.

Oil well records and levels, by J. F. Carll: Pennsylvania Second Geological Survey, Report of Progress, 1876–1877, Volume II, 398 pages, Harrisburg, 1877.

The geology of the oil regions of Warren, Venango, Clarion, and Butler counties, by J. F. Carll: Pennsylvania Second Geological Survey, Report for 1875–1879, Volume III, 482 pages, Harrisburg, 1880.

The geology of Erie and Crawford counties, by I. C. White: Pennsylvania Second Geological Survey, Report of Progress, 1879, Volume QQQQ, 406 pages, Harrisburg, 1881.

Geological report on Warren County and neighboring oil regions, by J. F. Carll: Pennsylvania Second Geological Survey, Report for 1880–1883, Volume I[4], 439 pages, Harrisburg, 1883.

O. S. C. Carter, artesian water supplies for Philadelphia: Franklin Institute Journal, 1893, volume 135, page 58; volume 136, pages 230–239, 298–305.

United States Geological Survey Folio No. 82, 1902, by M. R. Campbell.

United States Geological Survey Folio No. 94, 1903, by M. R. Campbell.

Gaines oil field of northern Pennsylvania, by M. L. Fuller: Twenty-second Annual Report of the United States Geological Survey, 1900–1901, pages 579–627.

RHODE ISLAND.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Kent County:	*Feet*	*Inches.*	*Gallons*	*Feet.*	
Warwick	502	8	120	No flow.	Hard water.
Newport County.					
Fort Greble	762				Good supply of water.
Providence County:					
Arlington	402	8		- 32	
Providence	400	6	85	No flow.	
Do	460	6	110	No flow.	
Saylesville	1,436		15	No flow.	Abandoned.

SOUTH CAROLINA.

Abbeville County:					
Abbeville	504	8	80	- 3	
Greenwood	400	8	40	- 4	
Aiken County:					
Aiken[1]	558	8-6	50	- 170	In granite.
Barnwell County:					
Bamberg[2]	470-555	1½-2	35-40	+12-30	Several wells.

[1] Record, U. S. Geol. Surv. Bull. No. 138, p. 220. [2] Ibid., p. 221.

SOUTH CAROLINA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Beaufort County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Beaufort[1]	800				
Mays River Neck	800			− 1	Very sulphurous water.
Charleston County:					
Charleston[2]	1,970		250	+ 4	Temp., 99.5°.
Do.[3]	1,260		30	+25	Saline water; temp., 87°.
Do	1,950	3½	167		Temp., 99°.
Do	1,970	2 11/16	104		Do.
Do	2,050	4	451		Do.
Do	1,945	5	695		Do.
Charleston (vicinity)[4]	425–475				Several wells.
Charleston	2,000				
Johns Island	500	6	11	Flows.	Temp., 70°.
Chester County:					
Chester	700				In granite; unsuccessful.
Do	500	8			Unsuccessful.
Colleton County:					
Green Pond	503	3	1	Flows.	Temp., 70°.
Jacksonboro	420	3	4	Flows.	Temp., 72°.
Walterboro	490	6	Many.	−30	Soft water.
Florence County:					
Florence[5]	1,335	10–8	100	−20	Lowest water at 1,215 to 1,220 feet.
Do	420		Many.		Fine water.
Georgetown County:					
Georgetown	400?		Not any.		
Hampton County:					
Hampton	800			Flows.	
Do	583	6	Many.	− 9	Soft, irony water.
Peoples	850	6	100	Flows.	Temp., 76°.
Varnville	983	6	Many.	−12	
Kershaw County:					
Camden	618–625		Many.	−20	2 wells.
Laurens County:					
Sullivans Island	1,308	12–3	10		Temp., 87°.
Marion County:					
Marion	1,244	8–6	½	Flows.	
Orangeburg County:					
Orangeburg[6]	1,160	6–2½	Many.	−52	Pumped at 300 feet.

[1] Analysis, U. S. Geol. Surv. Bull. No. 138, p. 220.
[2] Record, Artesian Wells Report of Scientific Committee: Municipal Rept. Charleston, 1881, pp. 3–4, plate.
[3] Analysis, U. S. Geol. Surv. Bull. No. 138, p. 212.
[4] Ibid., pp. 214–216.
[5] Record and analysis, ibid., 218–219.
[6] Record, ibid., p. 220.

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Artesian wells report of scientific committee, etc.: Municipal Report of the City of Charleston, S. C., 1881, 61 pages, plates, Charleston, 1882.

Artesian well prospects in the Atlantic Costal Plain region, by N. H. Darton: U. S. Geological Survey Bulletin No. 138, 232 pages, plates, Washington, 1896.

SOUTH DAKOTA.

Location.	Depths.	Diameter.	Yield per minute.	Pressure.	Remarks.
Aurora County:	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
T. 101, R. 64, sec. 1	630				
T. 101, R. 64, sec. 3	800	2	50		
T. 101, R. 64, sec. 6	730	2	30		
T. 101, R. 64, sec. 17	960	2	60		
T. 102, R. 63, sec. 10	536				
Do.[1]	613	2	3		
T. 102, R. 63, sec. 11	460				
Crystal Lake Township, sec. 17.	850	4½	600	55	
T. 102, R. 64, sec. 19	800	3–2	40	78	
Do	800	3–2	40		
T. 102, R. 64, sec. 29	600	2	8		
T. 102, R. 65, sec. 25	795	2	10	40	
T. 102, R. 66, sec. 7	800	2	120		
T. 102, R. 66, sec. 17	835	4½	400		

SOUTH DAKOTA—Continued.

Location.	Depths.	Diameter.	Yield per minute.	Pressure.	Remarks.
Aurora County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
T. 103, R. 63, 5 miles southeast of Plankinton.	705	3	200	.....	
T. 103, R. 63, sec. 4	500	.....	.....	.....	
T. 103, R. 63, sec. 8	755	3	100	80	
T. 103, R. 63, sec. 9	470	.....	.....	.....	
T. 103, R. 63, sec. 10	900, 425	2	±4	+12	
T. 103, R. 63, sec. 11	830, 440	2	4	10	
T. 103, R. 63, sec. 13	420	.....	.....	.....	
T. 103, R. 63, sec. 24	425	.....	.....	.....	
T. 103, R. 63, sec. 25	420	.....	.....	.....	
T. 103, R. 63, sec. 26[1]	490, 580	2	10	.....	
T. 103, R. 63, sec. 28[2]	716	3	200	.....	
T. 103, R. 63, sec. 32	623	3-2	15	.....	
T. 103, R. 63, sec. 35	484	4-3	.....	.....	
Do	507	.....	.....	.....	
(?)	530	2	30	.....	
City of Plankinton	745-830	4½-3	60-225	.....	The 830-foot well has sure of 91 pounds.
Plankinton Township well, R. 64, sec. 22.	775	4½	200	55	
T. 103, R. 64, sec. 27	765	.....	.....	.....	
T. 103, R. 64, sec. 29	715	.....	1,200	.....	
T. 103, R. 65, sec. 31	830	2	40	.....	
T. 103, R. 66, sec. 10	900	2	±4	+12	Whitelake City well
T. 103, R. 66, sec. 11	830	2	4	±10	Whitelake City well
T. 103, R. 66, sec. 34	842	6	.....	.....	
White Lake	863	4	150	35	
White Lake (7½ miles northwest).	814	2-1½	35	Flows.	
White Lake (10 miles northwest).	918	3-1½	5	Flows.	
T. 104, R. 63, sec. 1	470	2	4	.....	
T. 104, R. 63, sec. 2	740	.....	.....	.....	
T. 104, R. 63, sec. 3	508	.....	.....	.....	
T. 104, R. 63, sec. 10	440	.....	.....	.....	
T. 104, R. 63, sec. 15	465	.....	.....	.....	
T. 104, R. 63, sec. 17	540	.....	.....	.....	
T. 104, R. 63, sec. 20	530	.....	.....	.....	
T. 104, R. 63, sec. 21	523-575	4½	150	45	
T. 104, R. 63, sec. 22[1]	525	4½-3	168	.....	
T. 104, R. 63, sec. 26	426	.....	.....	.....	
T. 104, R. 63, sec. 35	400, 450	.....	.....	.....	
T. 104, R. 64, sec. 34	590	.....	.....	.....	
Do	545	2	2½	15	
T. 104, R. 65, sec. 26	728	2	84	.....	
T. 104, R. 66, sec. 2	844	2	105	.....	
T. 104, R. 66, sec. 3	922	2	75	.....	
T. 105, R. 63, sec. —	475	2	5	.....	
T. 105, R. 63, sec. 2	400	.....	.....	.....	
T. 105, R. 63, sec. 7	580	.....	.....	.....	
T. 105, R. 63, sec. 24	487	2	32	.....	
Do	500	.....	.....	.....	
T. 105, R. 63, sec. 26	475, 490	.....	.....	.....	
T. 105, R. 63, sec. 28	508, 560	.....	.....	.....	
T. 105, R. 63, sec. 35	620	.....	.....	.....	
Do.[3]	760	.....	.....	.....	
T. 105, R. 64, sec. 2	640	.....	.....	.....	
T. 105, R. 64, sec. 22	563	.....	.....	.....	
T. 105, R. 66, sec. 24	953	2	60	.....	
T. 105, R. 66, sec. 32	1,222	3	.....	.....	
Beadle County:					
T. 109, R. 61	670	1½	.....	.....	
T. 109, R. 62	782-916	1½-9	20-250	125	
T. 109, R. 63	806-856	1½	Many.	.....	
T. 109, R. 64	830, 910	1½	45	.....	
T. 110, R. 59	748, 730	2, 1½	33, 6	.....	
Do	857	2	50	.....	
T. 110, R. 60	746-930	1½-4	35, 930	100	Pressure given is fo 930-foot well.
T. 110, R. 61	879	2	150-200	60-100	
Do	742	2	30	.....	
Do	900	2, 3	130, 500	125	2 wells.
T. 110, R. 62	792 804	1½	50	.....	
Do.[4]	784-1,139	1½-3	350-2,250	120-165	Huron town wells.
T. 110, R. 63	812-870	1½-2	26-30	.....	
T. 110, R. 64	847	2	100	.....	
T. 110, R. 65	863-910	1½	31-50	.....	
T. 111, R. 59	925, 940	2	50, 20	.....	

[1] Record, U. S. Geol. Surv., 18th Ann. Rept., part 4, pl. 40.
[2] Ibid., Mitchell folio No. 99, p. 3.
[3] Ibid., p. 2.
[4] U. S. Geol. Surv., 17th Ann. Rept., part 22-23.

SOUTH DAKOTA—Continued.

ion.	Depth.	Diameter.	Yield per minute.	Pressure.	Remarks.
-Continued.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
.....	757-836	1¼-3	25-360	.....	
.....	744-925	1¼-2	35-300	.....	
.....	780-918	2-1¼	35-114	.....	
.....	784-870	1¼-2	43-100	.....	
.....	930	8-5	330	137	Wolsey well.
.....	900, 1,000	1¼	20, 80	.....	
.....	913-945	1¼	25-40	.....	
.....	779	3	400-600	120	
.....	870	1¼	40	.....	
.....	778, 917	1¼-4	35	.....	
.....	746-968	1¼-3	45-600	125?	
.....	780-950	1¼-3	25-240	63	Pressure refers to only one well.
.....	601-870	1¼-2	16-200	20-90	
.....	900	1¼	45	.....	
.....	955	1¼	40	.....	
.....	854	1¼	40	.....	
.....	832, 810	1¼, 2	130, 200	(?), 115	
.....	740-810	3-1¼	25-125	.....	
.....	775-815	2	50-120	.....	
.....	890	2	300	100	
.....	988	2¼	200	.....	
.....	800-950	1¼	30-50	.....	
.....	953	4-3	1,260	150	Hitchcock well.
.....	792-1,118	1¼-4¼	20-1,435	.....	One 175-pound pressure.
.....	933-1,000	1¼	26-70	.....	
.....	1,038	2	8	.....	
nty:					
.....	885, 920	2	.....	.....	30 pounds pressure in 885-foot well.
.....	630-660	3	95-100	45	
.....	530-855	1¼-3	15-252	40-66	
.....	620	6	700	.....	Springfield city well.
.....	592-828	1¼-8	72, 3, 292	86	
.....	735-1,000	2-6	25-70	12-14	
.....	862, 897	6	1,400 1,600	62, 58	Choteau Creek wells.
.....	576-645	2, 3	11-100	40	
.....	552-752	1-8	13-150	.....	40 pounds pressure in 752-foot well.
.....	667, 857	2, 4¼	75, 1,000	30	City of Tyndall.
.....	1,074	3-2¼	.....	2¼	Layson well.
.....	730-828	2-3	26-97	.....	Yield decreased to 50.
.....	822	2	52	.....	
.....	590, 680	6	9	.....	Scotland wells.
.....	590-700	2-7	Few.	55-65	At Hutterisches Colony.
.....	565	.....	.....	.....	
ity:					
.....	556	4¼	Several.	—42	Pressure not sufficient to afford a flow. To granite.
.....	910	1¼	57	.....	
.....	900, 940	1¼	14, 43	168	
.....	930, 960	2-8	106, 306	.....	
.....	898-980	1¼-2	33-96	.....	
.....	1,000	1¼-2	96	.....	Warner town well.
.....	903-1,015	1¼-2	35-96	20-60	Temperature of 66° reported in 2 wells.
.....	1,070	1¼	46	.....	Temperature of flow is 70°.
.....	940-1,000	2	15-76	.....	Town of Ferney.
.....	900-960	1¼-2	39-70	125	
.....	920-910	1¼	25-34	120	
.....	950, 1,000	1¼	30	.....	
.....	1,080	1¼	37	.....	
.....	920-977	1¼	10-105	.....	
.....	922, 960	5-6	830	135	Groton town wells Nos. 1 and 2.
.....	920-935	1¼-2	15-123	.....	
.....	900	2	95	.....	
.....	.....	1¼-2	31-96	.....	
.....	918-1,117	1¼-6	250-1,000	40-138	
.....	1,200	6	450	210	
.....	1,300	6-4¼	1,350	.....	Aberdeen city well No. 3.
.....	1,300	8-4¼	1,000	.....	Aberdeen city well No. 4.
.....	1,070-1,167	1¼	25-53	.....	
.....	942	4-2¼	150	137	

urv., 17th Ann. Rept., part 2, pp.

Olivet folio No. 96, p. 1.
nn. Rept., part 4, p. 586.

[6] Ibid., p. 587.
[7] Ibid., Water-Sup. and Irr. Paper No. 34, pl. 7.
[8] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 16-18, pl. 72.
[9] Ibid., pp. 15-17.

SOUTH DAKOTA—Continued.

Location.	Depths.	Diameter.	Yield per minute.	Pressure.	Remarks.
Aurora County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
T. 103, R. 63, 5 miles southeast of Plankinton.	705	3	200	.....	
T. 103, R. 63, sec. 4	500	.....	.....	.....	
T. 103, R. 63, sec. 8	755	3	100	80	
T. 103, R. 63, sec. 9	470	.....	.....	.....	
T. 103, R. 63, sec. 10	900, 425	2	±4	+12	
T. 103, R. 63, sec. 11	830, 440	2	4	10	
T. 103, R. 63, sec. 13	420	.....	.....	.....	
T. 103, R. 63, sec. 24	425	.....	.....	.....	
T. 103, R. 63, sec. 25	420	.....	.....	.....	
T. 103, R. 63, sec. 26[1]	490, 530	2	10	.....	
T. 103, R. 63, sec. 28[2]	716	3	200	.....	
T. 103, R. 63, sec. 32	623	3–2	15	.....	
T. 103, R. 63, sec. 35	484	4–3	.....	.....	
Do	507	.....	.....	.....	
(?)	530	2	30	.....	
City of Plankinton	745–830	4¼–3	60–225	.....	The 830-foot well has pr sure of 91 pounds.
Plankinton Township well, R. 64, sec. 22.	775	4¼	200	55	
T. 103, R. 64, sec. 27	765	.....	.....	.....	
T. 103, R. 64, sec. 29	715	.....	1,200	.....	
T. 103, R. 65, sec. 31	830	2	40	.....	
T. 103, R. 66, sec. 10	900	2	±4	+12	Whitelake City well No
T. 103, R. 66, sec. 11	830	2	4	±10	Whitelake City well No
T. 103, R. 66, sec. 34	842	6	.....	.....	
White Lake	863	4	150	35	
White Lake (7½ miles northwest).	814	2–1¼	35	Flows.	
White Lake (10 miles northwest).	918	3–1¼	5	Flows.	
T. 104, R. 63, sec. 1	470	2	4	.....	
T. 104, R. 63, sec. 2	740	.....	.....	.....	
T. 104, R. 63, sec. 3	508	.....	.....	.....	
T. 104, R. 63, sec. 10	440	.....	.....	.....	
T. 104, R. 63, sec. 15	465	.....	.....	.....	
T. 104, R. 63, sec. 17	540	.....	.....	.....	
T. 104, R. 63, sec. 20	530	.....	.....	.....	
T. 104, R. 63, sec. 21	523–575	4¼	150	45	
T. 104, R. 63, sec. 22[1]	525	4¼–3	168	.....	
T. 104, R. 63, sec. 26	426	.....	.....	.....	
T. 104, R. 63, sec. 35	400, 450	.....	.....	.....	
T. 104, R. 64, sec. 34	590	.....	.....	.....	
Do	545	2	2¼	15	
T. 104, R. 65, sec. 26	728	2	84	.....	
T. 104, R. 66, sec. 2	844	2	105	.....	
T. 104, R. 66, sec. 3	922	2	75	.....	
T. 105, R. 63, sec. —	475	2	5	.....	
T. 105, R. 63, sec. 2	400	.....	.....	.....	
T. 105, R. 63, sec. 7	580	.....	.....	.....	
T. 105, R. 63, sec. 24	487	2	32	.....	
Do	500	.....	.....	.....	
T. 105, R. 63, sec. 26	475, 490	.....	.....	.....	
T. 105, R. 63, sec. 28	508, 560	.....	.....	.....	
T. 105, R. 63, sec. 35	620	.....	.....	.....	
Do.[3]	760	.....	.....	.....	
T. 105, R. 64, sec. 2	640	.....	.....	.....	
T. 105, R. 64, sec. 22	563	.....	.....	.....	
T. 105, R. 66, sec. 24	953	2	60	.....	
T. 105, R. 66, sec. 32	1,222	3	.....	.....	
Beadle County:					
T. 109, R. 61	670	1¼	.....	.....	
T. 109, R. 62	782–916	1¼–9¼	20–250	125	
T. 109, R. 63	806–856	1¼	Many.	.....	
T. 109, R. 64	830, 910	1¼	45	.....	
T. 110, R. 59	748, 730	2, 1¼	33, 6	.....	
Do	857	2	50	.....	
T. 110, R. 60	746–930	1¼–4	35, 930	100	Pressure given is for 930-foot well.
T. 110, R. 61	879	2	150–200	60–100	
Do	742	2	30	.....	
Do	900	2, 3	130, 500	125	2 wells.
T. 110, R. 62	792, 804	1¼	50	.....	
Do.[4]	784–1,139	1¼–3	350–2,250	120–165	Huron town wells.
T. 110, R. 63	812–870	1¼–2	26–30	.....	
T. 110, R. 64	847	2	100	.....	
T. 110, R. 65	863–910	1¼	31–50	.....	
T. 111, R. 59	925, 940	2	50, 20	.....	

[1] Record, U. S. Geol. Surv., 18th Ann. Rept., part 4, pl. 40.
[2] *Ibid., Mitchell folio No. 99, p. 3.*
[3] Ibid., p. 2.
[4] U. S. Geol. Surv., 17th Ann. Rept., part 2, 22–23.

SOUTH DAKOTA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Pressure.	Remarks.
Charles Mix County—Con.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
T. 98, R. 64	772	2	200	52	
T. 98, R. 65	920, 940	2	6, 11	2-8	
T. 98, R. 66	820-950	2-3	50-65	24-30	
T. 98, R. 67	800-991	1-3	6-65	.....	Various pressures given, the greatest being 63 pounds.
T. 98, R. 68	800-1,110	1¼-3	10-150	3-80	
Do	1,220	6	.....	.....	No flow.
T. 98, R. 69	644	6	50	+24	
T. 99, R. 66	840	1¼	20	+24	
T. 99, R. 67[1]	730-950	1¼-3	4-50	−50	Greatest pressure reported.
T. 99, R. 68	720-1,006	1-3	2-78	−40	Do.
T. 99, R. 69	944, 966	3, 2	60	50	
T. 99, R. 70	840-1,000	1¼-3	10-30	20-26	
T. 100, R. 67	734-875	1¼-3	20-120	−87	Do.
T. 100, R. 68	720-930	1-2	7-31¼	−13	Do.
T. 100, R. 69	856-1,030	2	15-125	15	Pressure given is for 1 well.
T. 100, R. 70	890, 900	1¼, 2	16	30	
T. 100, R. 71	600-868	8	500-3,000	.....	
Clark County:					
T. 113, R. 58	990	2	17	.....	
T. 114, R. 59	1,100, 1,038	2	6, 8	.....	
Do	866-946	1¼	.....	.....	
Clark	1,200	.....	.....	.....	2 unsuccessful wells.
T. 117, R. 59[2]	1,020-1,200	1¼-6	15-35	.....	
T. 118, R. 59	1,013-1,080	1¼-2	25-150	.....	
Clay County:					
T. 92, R. 51, sec. 33	400	3-2	Few.	.....	Water rises a few feet above the surface.
Vermilion	507	3	Few.	.....	
T. 93, R. 51, sec. 29	400	1¼	3	.....	Flow decreasing.
T. 93, R. 51, sec. 31	410	1	1	.....	Do.
T. 93, R. 52, sec. 28	400	2	.....	.....	
T. 94, R. 52, sec. 11	402	2	5	.....	Do.
T. 94, R. 52, sec. 15	400	1¼	Many.	.....	Do.
T. 94, R. 53, sec. 33	500	2	Few.	.....	Irony; flow decreasing.
T. 95, R. 52, sec. 9	500	3-2	3	.....	Soft; flow decreasing.
T. 95, R. 52, sec. 17[3]	507	.....	.....	.....	
Custer County:					
Buffalo Gap	700	.....	.....	.....	2 unsuccessful borings.
Davison County:					
T. 101, R. 60[4]	413-525	2	25-45	.....	Very hard rock bottom in 477-foot well.
T. 101, R. 61	425-640	1¼-2	15-48	.....	Depths increase regularly from northeast to southwest in this township.
T. 101, R. 62[5]	480-775	.....	60	.....	
T. 102, R. 61	500	.....	.....	.....	
T. 102, R. 62	449-642	2-1¼	20-90	.....	
T. 103, R. 60[6]	431-550	.....	35	13	Yield and pressure for 550-foot well sunk in 1896.
T. 103, R. 60[7]	765	.....	.....	.....	In Mitchell; flows at 285, 376, 445, and 540 feet; quartzite from 540 to 765 feet.
Do	433-586	2-8	20-600	13-28	In Mitchell and vicinity.
T. 103, R. 61	410-500	2	110-120	.....	
T. 103, R. 62	400-495	2-4¼	35-70	.....	
	646	4¼	700	.....	Flows at 350, 470, and 620 feet.
T. 104, R. 60[8]	400-507	3-4¼	10-100	.....	
T. 104, R. 61	400-653	2-3	22-210	.....	Several flows.
T. 104, R. 62[8]	405-601	2-4¼	5-156?	.....	
Day County:					
Webster	1,716	.....	−69	.....	Water rises to 220 feet.
Do	1,550?	2	.....	.....	Unsuccessful.
Andover[9]	1,075	6¼	300	90	Saline.
T. 122, R. 59, sec. 4	1,080	1¼	40	85	
T. 123, R. 58	1,210	3	.....	.....	
T. 124, R. 58	1,240	.....	.....	.....	Water just flows.
T. 124, R. 58, sec. 6	930	1¼	28	70	
T. 124, R. 58	1,200	1¼	15	40	
T. 124, R. 59, sec. 2	930	1¼	40	75	
T. 124, R. 59, sec. 36	970	1¼	35	90	
Dewey County:					
Cheyenne Agency[10]	1,337	8-4	500	205	Temp., 90° or 92°.

[1] Record U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 44-45.
[2] Ibid., 18th Ann. Rept., 1897, part 4, pp. 18, 21.
[3] Ibid., Parker folio No. 97, p. 21.
[4] Ibid., Alexandria folio No. 100, p. 2.
[5] Ibid., Mitchell folio No. 99, pp. 2-3.
[6] Ibid., 17th Ann. Rept., part 2, pp. 39-40, 44.
[7] U. S. Geol. Surv. Mitchell folio No. 99.
[8] Record, ibid., 18th Ann. Rept., part 4, p. 575.
[9] Ibid., 17th Ann. Rept., part 2, p. 19.
[10] Ibid., 18th Ann. Rept., part 4, p. 588.

SOUTH DAKOTA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Pressure.	Remarks.
Douglas County:	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
Delmont[1]	821	2	60	.....	
Armour[1]	737	6	1,500	55	
Armour Mill Company's well.[1]	800	8	1,500	.....	
T. 98, R. 63, sec. 20	722	1¼	Many.	.....	
T. 98, R. 64, sec. 2	901	8-6	1,200	.....	
T. 98, R. 64, sec. 24	786	2	+20	.....	
T. 98, R. 65, sec. 2[2]	860	6	900	.....	
T. 99, R. 63, sec. 35	708¼	8-6	2,100	75	
T. 99, R. 65, sec. 14	925	4	600-700	.....	
T. 99, R. 65	1,010	6	1,000	.....	
T. 100, R. 62, sec. 16	600	2	Many.	.....	
T. 100, R. 62, sec. 18	1,025	.....	1,025	.....	
Flensburg	611	2	60	.....	
Flensburg (one-half mile west).	651	2	.....	.....	
Flensburg (three-fourths mile west).	775	2	65-70	.....	
T. 100, R. 63, sec. 15	750	4	600-700	.....	County well.
T. 100, R. 64, sec. 26	937	6	900	40	Do.
Do	975	4	1,000	.....	Do.
Edmunds County:					
T. 120, R. 67	1,141	1¼	25	.....	
T. 121, R. 66	987-1,100	1¼-2	12-100	.....	
T. 121, R. 67	1,025-1,220	1¼	20-50	.....	
T. 121, R. 68	1,155-1,295	1¼-3	40-50	.....	
T. 121, R. 69	1,355, 1,240	1¼	40, 25	.....	
T. 121, R. 70	1,300-1,370	1¼	35	.....	
T. 121, R. 71	1,500-1,569	1¼	20	.....	
T. 122, R. 66	1,000-1,090	1¼-2	15-70	.....	
T. 122, R. 67	1,000-1,140	1¼	5-40	.....	
T. 122, R. 68	1,145-1,170	1¼	20-35	.....	
T. 122, R. 69	1,305-1,360	1¼	35-70	.....	
T. 122, R. 71	1,526	1¼	2	+12	Clear, soft water; 56°.
T. 123, R. 66	1,075-1,125	2-1¼	25-90	110	Pressure refers to foot well.
T. 123, R. 67	1,100, 1,160	1¼	25-35	.....	
T. 123, R. 68	1,195-1,245	2-3	97-150	.....	The 1,245-foot wel town of Ipswich.
T. 123, R. 69	1,370-1,420	1¼	30	.....	
T. 123, R. 70	1,498	2	3¼	20	Roscoe City.
T. 124, R. 66	1,125-1,148	1¼	40-41	.....	
T. 124, R. 67	1,150-1,370	1¼-2	15-120	.....	
T. 124, R. 68	1,225-1,350	1¼	25-45	.....	
T. 124, R. 69	1,356	2	60	.....	
Fall River County:					
Ardmore	1,500	.....	.....	.....	Unsuccessful.
Argentine[3]	550	.....	.....	.....	
Edgemont[4]	1,125	.....	Several.	.....	Plugged at 700 feet at 509 feet.
Edgemont (near)	960	.....	Several.	.....	Water from 578 fee
Minnekahta[5]	1,348	.....	.....	.....	
Smithwick (7 miles southwest).	600	.....	.....	.....	In progress.
Faulk County:					
T. 116, R. 66	970	1¼	30	.....	
T. 117, R. 66	913-1,054	1¼	45-65	.....	
T. 117, R. 67	1,000, 997	1¼	48-27	.....	
T. 117, R. 68	1,095, 1,156	1¼-2	75, 90	.....	
T. 117, R. 69 (Orient)	1,232	.....	60	25-34	
Orient (4 miles northeast).[6]	1,215	6-5¼	950	.....	
T. 117, R. 70	1,552	3-1¼	17	.....	
T. 118, R. 66	938-1,041	1¼	35-55	.....	
T. 118, R. 67	1,001-1,125	1¼-2	30-75	.....	First flow at 850 fe
T. 118, R. 68	1,030-1,185	1¼	20-45	.....	
T. 118, R. 69	1,220-1,466	1¼-4	25-40	60	Pressure is for 1 we foot well in Faul
T. 118, R. 70	1,183-1,608	2-3	45-100	.....	
T. 119, R. 66	970-1,008	1¼-2	35-68	.....	
T. 119, R. 67	1,030-1,172	1¼	20-160	.....	
T. 119, R. 68	1,110-1,165	1¼, 2	30, 150	.....	
T. 119, R. 69	1,206-1,456	2-3	25-100	.....	
T. 119, R. 70	1,367-1,402	2	100, 185	.....	
T. 119, R. 71	1,545	2	45	.....	
T. 120, R. 67	1,030-1,140	1¼-3	25-160	.....	

[1] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 46-50.
[2] Ibid., part 4, p. 575.
[3] Analysis, ibid., 21st Ann. Rept., 1899-1900, part 4, p. 570.
[4] Ibid., pp. 568, 571.
[5] Ibid., p. 573.
[6] Record, ibid., 17th Ann. Rept., part p. 22.

SOUTH DAKOTA—Continued.

ation.	Depth.	Diameter.	Yield per minute.	Pressure.	Remarks.
y—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
68	1,025-1,125	1¼	(?)-25	(?)-85	
69	1,197-1,287	1¼-2	10-125		
70	1,342-1,512	1¼-2	12-100		
71	1,505-1,570	2-3	27-35		
72	1,580-1,650	2	30-70		
y:					
48, sec. 22, NE.	407	2	2	16	
48, sec. 18, SE.	422	2	10	7	
48, sec. 7, NW.	510	2	30	13	
49, sec. 13, NE.	459	2	45	17	
nty: [1]					
dall	610	4	600		Flow diminishing.
68, sec. 28, NE.	800	3	320		
68, sec. 29, NE.	730	6-4	800		Flow slightly diminished
68, sec. 30	714-892	3	50-270		Hard water; temp., 80° t 86°.
y:					
67, sec. 7, SW.	1,474	3-2			Pump.
68, sec. 21, NW.	1,611	2			Water to −80 feet.
68, sec. 28, NE.	838	1¼	50		
66, sec. 1, NE.	931	1¼	41		
66, sec. 8, NE.		1¼			
66, sec. 30, NW.	1,269	2-1¼	40		
67, sec. 4, SW.	1,125	1¼	50		
67, sec. 5, NW.	1,165	2-1¼	14		
67, sec. 7	1,272		Few.	40	
67, sec. 18	1,343	3	350	125	
67, sec. 26, SW.	1,246		40		
67, sec. 33	1,375	3	1,350	119	
68, sec. 2, SW.	1,158	1¼	135		
68, sec. 7	1,200	4	50		
68, sec. 10	1,140	3¼			
	1,139	6¼-4¼	360	120	
ost Creek Ranch	1,142	3-2	40		
69, sec. 9, SE.	1,300	1¼	30		
69, sec. 11	1,207	2	100		
70, sec. 5, SW.	1,400	2	20		
70, sec. ?	1,440	1¼	30		
66, sec. 11, SW.	980	2	100?	+8	
66, sec. 15, SW.	967	1¼			
66, sec. 18, SE.	1,163	1¼	40		
66, sec. 20, SW.	1,058	1¼	35		
66, sec. 24, SE.	1,002	1¼	50		
66, sec. 24	980	1¼	35		
67, sec. 14, SE.	1,155	2¼			
67, sec. 15, SE.	800	2			
67, sec. 25, SE.	1,168	1¼	35		
67, sec. 17, SW.	1,137				
67, sec. 25	1,140	3	400	128	
68, sec. 29, SW.	1,125	3			
69, sec. 13, NE.	1,162	2	100		
69, sec. 14, NW.	1,215	2			
69, sec. (?)	1,200				
69, sec. 33, SE.	1,214	1¼	60		
70, sec. 1, SW.	1,258	2	150		
70, sec. (?)	1,220	2	30		
66, sec. 9, NE.	966	2	50		
66, sec. 11	1,070	1¼	35		
66, sec. 12, NW.	1,011	1¼	35		
66, sec. 14, SE.	960	1¼	40		
66, sec. 22, NE.	958	1¼	42		
66, sec. 35¼, W.	1,010	1¼	35		
67, sec. 30, SW.	1,102	1¼	25		
68, sec. 8, SW.	1,170	1¼	35		
68, sec. 9, SW.	1,185	1¼	30		
68, sec. 12, NE.	1,050	1¼	40		
68, sec. 19, NE.	1,140	1¼	35		
68, sec. 27, SE.	1,272				
69, sec. (?)	1,398		25		
69, sec. 14, SE.	1,197	2			
70, sec. 2, NW.	1,270	2	80		
70, sec. 8, SW.	1,380	2	120		Gas with second flow a 1,375 feet.
70, sec. 15	1,303	3-1¼	15 or 25		
70, sec. 19, NE.	1,305	1¼	55		
70, sec. 20, NE.	1,350	2	120		
66, sec. 35, NE.	993	1¼			
67, sec. 12, NW.	1,015	1¼			
68, sec. 10, NE.	1,184	1¼			
68, sec. 20	1,100	4¼-2	180		

[1] U. S. Geol. Surv., 17th Ann. Rept., p. 58.

[2] Ibid., p. 26.

SOUTH DAKOTA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Pressure.	Remarks.
Hand County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
T. 115, R. 68, sec. 22, NE	1,065	1¼	60	.....	
T. 115, R. 69, sec. 10, SE	.....	2	.....	.....	
T. 115, R. 69, sec. 14, SW	1,335	1¼	35	.....	
T. 115, R. 69, sec. 24, NW	1,242	.....	16	.....	
T. 115, R. 70, sec. 14, NE	1,370	2	135	.....	
T. 115, R. 70, sec. 28, SW	1,300	2	100	.....	
T. 116, R. 67, sec. 15, SE	966	1¼	35	.....	
T. 116, R. 67, sec. 26	853	1¼	.....	.....	
T. 116, R. 68, sec. 28, NE	1,115	1¼	68	.....	
T. 116, R. 69, sec. 35, SW	1,260	1¼	40	.....	
Hanson County:					
T. 101, R. 58[1]	412	.....	.....	.....	
T. 103, R. 59[1]	400–470	.....	.....	.....	
T. 104, R. 57, sec. 3	532	2	2	+ 6	
T. 104, R. 57, sec. 7	510	3–2	16	.....	
T. 104, R. 57, sec. 8[2]	589, 600	1¼, 2	20, 50	.....	
T. 104, R. 57, sec. 17	510	3	2	.....	
T. 104, R. 57, sec. 21	550	2	2	.....	
T. 104, R. 57, sec. 22	543	2	50	.....	
T. 104, R. 57, sec. 24	555	2	+1	.....	
T. 104, R. 57, sec. 27	508	2	4	.....	
T. 104, R. 57, sec. 30[1]	558	.....	.....	.....	
T. 104, R. 58, sec. 9	535	2	5	.....	
T. 104, R. 58, sec. 12[3]	483	4	35	20	
T. 104, R. 58, sec. 13[2]	550	2	150	.....	
T. 104, R. 58, sec. 14[2]	528	2–1¼	30	.....	
T. 104, R. 58, sec. 17	440	1	Few.	.....	
Hughes County:					
Pierre (city well)	1,281	8–6	2,088	.....	
Pierre	1,160–1,537	.....	.....	210	Pressure given is greatest reported.
Pierre (northeast of)	1,645	3–1¼	115	.....	
East Pierre[4]	1,192	.....	900	+160	
Harrold[4]	1,453	4	84	+ 20	
Hutchinson County:					
T. 97, R. 56	445, 480	2	.....	.....	
Menno	417	6	([5])	.....	Low pressure.
T. 97, R. 57	406–747	1¼–2	Many.	25	
T. 97, R. 59	480–620	1¼–2	30–50	25–35	
T. 97, R. 60	540–760	1¼–2	40–100	35–60	
Do.[6]	842	4¼	700	9	Tripp town well.
T. 97, R. 61	945	.....	.....	.....	
T. 98, R. 58	420	.....	.....	.....	
T. 98, R. 59	400–450	1¼–2	4–15	.....	
T. 98, R. 60	470–580	2–5	16–120	.....	
T. 98, R. 61	482–560	1¼–3	13–60	.....	
T. 99, R. 59	490	2	.....	.....	
T. 99, R. 60[7]	400–540	1¼–3	10–150	.....	
Do	522	6	5	.....	Parkston city well.
Do	542	3	30	20	Do.
T. 99, R. 61	490–572	1¼–2	8–50	.....	
T. 100, R. 59[6]	410	.....	.....	.....	
T. 100, R. 60	420–560	2	3–10	.....	
T. 100, R. 61[8]	419–585	2–3	1–90	.....	
Hyde County:					
Afton (1 mile east)	1,370	2	40	.....	
Afton (3 miles east)	1,350	2	18	.....	
Edwin	1,445	2–1¼	.....	.....	
Edwin (near)	1,360–1,396	1¼	25–34	.....	3 wells.
Highmore[7]	1,552	6	9	12–15	Temp., 72°.
Highmore (3 miles north)	1,487	2	120	.....	
Highmore (4 miles northeast).	1,490	2	120	.....	
Highmore (8 miles northeast).	1,397	3–2	70	.....	Mitchell ranch.
Highmore (3 miles northwest).	1,590	2	12	.....	
Highmore (14 miles northwest).	1,508	2	180	.....	
Highmore	1,631	3	14	.....	
Ree Heights (3 miles northwest).	1,440	2	100	.....	
Jerauld County:					
T. 106, R. 63	715–760	2–3	200–280	110–140	
T. 106, R. 64[9]	735–880	2¼	5–280	114	

[1] U. S. Geol. Surv. Alexandria folio No. 100.
[2] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pl. 84.
[3] Ibid., 18th Ann. Rept., part 4, p. 579.
[4] Ibid., 17th Ann. Rept., part 2, pl. 76.
[5] One-fourth of an inch stream.
[6] U. S. Geol. Surv. Water-Sup. and Irr. P No. 34.
[7] Record, ibid., 17th Ann. Rept., part 2, pp. 4 18th Ann. Rept., 1897, part 4, pp. 580–585.
[8] Ibid., 18th Ann. Rept., 1897, part 4, pp. 580
[9] Ibid., 17th Ann. Rept., part 2, p. 24.

SOUTH DAKOTA—Continued.

ion.	Depth.	Diameter.	Yield per minute.	Pressure.	Remarks.
-Continued.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
8	1,025-1,125	1¼	(?)-25	(?)-85	
9	1,197-1,287	1¼-2	10-125		
0	1,342-1,512	1½-2	12-100		
1	1,505-1,570	2-3	27-35		
2	1,580-1,650	2	30-70		
5, sec. 22, NE.	407	2	2	16	
5, sec. 18, SE.	422	2	10	7	
5, sec. 7, NW.	510	2	30	13	
9, sec. 13, NE.	459	2	45	17	
y:[1]					
all	610	4	600		Flow diminishing.
, sec. 28, NE.	800	3	320		
, sec. 29, NE.	730	6-4	800		Flow slightly diminished.
, sec. 30	714-892	3	50-270		Hard water; temp., 80° to 86°.
7, sec. 7, SW.	1,474	3-2			Pump.
8, sec. 21, NW.	1,611	2			Water to −80 feet.
8, sec. 28, NE.	838	1¼	50		
5, sec. 1, NE.	931	1¼	41		
6, sec. 8, NE.		1¼			
6, sec. 30, NW.	1,269	2-1¼	40		
7, sec. 4, SW.	1,125	1¼	50		
7, sec. 5, NW.	1,165	2-1¼	14		
7, sec. 7	1,272		Few.	40	
7, sec. 18	1,343	3	350	125	
7, sec. 26, SW.	1,246		40		
7, sec. 33	1,375	3	1,350	119	
8, sec. 2, SW.	1,158	1¼	135		
8, sec. 7	1,200	4	50		
8, sec. 10	1,140	3¼			
	1,139	6¼-4¼	360	120	
: Creek Ranch	1,142	3-2	40		
9, sec. 9, SE.	1,300	1¼	30		
9, sec. 11	1,207	2	100		
0, sec. 5, SW.	1,400	2	20		
0, sec. ?	1,440	1¼	30		
6, sec. 11, SW.	980	2	100?	+8	
6, sec. 15, SW.	967	1¼			
6, sec. 18, SE.	1,163	1¼	40		
5, sec. 20, SW.	1,058	1¼	35		
5, sec. 24, SE.	1,002	1¼	50		
6, sec. 24	980	1¼	35		
7, sec. 14, SE.	1,155	2¼			
7, sec. 15, SE.	800	2			
7, sec. 25, SE.	1,168	1¼	35		
7, sec. 17, SW.	1,137				
7, sec. 25	1,140	3	400	128	
8, sec. 29, SW.	1,125	3			
, sec. 13, NE.	1,162	2	100		
, sec. 14, NW.	1,215	2			
, sec. (?)	1,200				
, sec. 33, SE.	1,214	1¼	60		
, sec. 1, SW.	1,228	2	150		
, sec. (?)	1,240	2	30		
, sec. 9, NE.	966	2	50		
, sec. 11	1,070	1¼	35		
, sec. 12, NW.	1,011	1¼	35		
, sec. 14, SE.	960	1¼	40		
, sec. 22, NE.	958	1¼	42		
, sec. 35¼, W.	1,010	1¼	35		
, sec. 30, SW.	1,102	1¼	25		
, sec. 8, SW.	1,170	1¼	35		
, sec. 9, SW.	1,185	1¼	30		
, sec. 12, NE.	1,050	1¼	40		
, sec. 19, NE.	1,140	1¼	35		
, sec. 27, SE.	1,272				
, sec. (?)	1,338		25		
, sec. 14, SE.	1,197	2			
, sec. 2, NW.	±1,270	2	80		
, sec. 8, SW.	1,380	2	120		Gas with second flow at 1,375 feet.
, sec. 15	1,303	3-1¼	15 or 25		
, sec. 19, NE.	1,305	1¼	55		
, sec. 20, NE.	1,350	2	120		
, sec. 35, NE.	993	1¼			
, sec. 12, NW.	1,015	1¼			
, sec. 10, NE.	1,182	1¼			
, sec. 20	1,400	4¼-2	180		

S. *Geol. Surv., 17th Ann. Rept.,* [2] Ibid., p. 26.
6.

SOUTH DAKOTA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Pressure.	Remarks.
McPherson County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
T. 128, R. 66, sec. 25, NW.	1,170	1¼	26	.....	Water clear.
T. 128, R. 66, sec. 28, NW.	1,250	1¼	25	.....	Do.
T. 128, R. 66, sec. 30, SE.	1,250	1¼	25	.....	Do.
T. 128, R. 67, sec. 2, NW.	1,460	1¼	25	.....	Do.
T. 128, R. 67, sec. 13, SE.	1,725	1¼	25	.....	
T. 128, R. 67, sec. 14, NE.	1,350	1¼	35	.....	Do.
T. 128, R. 67, sec. 15, SE.	1,425	1¼	26	.....	Do.
T. 128, R. 67, sec. 25, NW.	1,300	1¼	35	.....	Do.
T. 128, R. 67, sec. 33, NW.	1,436	1¼	30	.....	Do.
Marshall County:					
Langford	1,050	6	400–500	60	
T. 125, R. 58, sec. 6	960	1¼	50	.....	
T. 125, R. 58, sec. 31	990	1¼	35	.....	
T. 125, R. 59, sec. 35, SE.	930	1¼	25	.....	
T. 125, R. 59, sec. 35	925	1¼	10	.....	
T. 125, R. 60, sec. 34	953	2	70	.....	
T. 126, R. 56, sec. 7	980	1¼	60	.....	
T. 126, R. 57, sec. 2	1,110	2	15	.....	
T. 126, R. 57, sec. 5	1,015	1¼	25, 30	.....	2 wells.
T. 126, R. 57, sec. 6	890	1¼?	35	.....	
T. 126, R. 57, sec. 7	960	1¼	10	.....	
T. 126, R. 57, sec. 9	1,200	1¼	25	.....	
T. 126, R. 57, sec. 12	968	1¼	25	.....	
T. 126, R. 57, sec. 22	1,018	1¼	30	.....	
T. 126, R. 57, sec. 34	1,034	1¼	25	.....	
T. 126, R. 58 sec. 1, SW	938	1¼	35	.....	
T. 126, R. 58 sec. 15, SW	958	1¼	45	.....	
T. 126, R. 58, sec. 19	950	2	95	.....	
T. 126, R. 58, sec. 26	965	1¼	10	.....	
T. 126, R. 58, sec. 28	940	1¼	30	.....	
T. 127, R. 57, sec. 12, NE.	940	1¼	6	.....	
T. 127, R. 57, sec. 23, NE.	1,152	2¼–1¼	40	.....	
T. 127, R. 57, sec. 32	1,010	1¼	35	.....	
T. 127, R. 58, sec. 32, SW.	922	1¼	35	.....	
Britton[1]	1,004	8–3¼	600	150	
Britton (near)	1,300	2–1¼	.....	.....	Water rises to –6
T. 128, R. 56, sec. 3	980	1	18	.....	
T. 128, R. 58, sec. 11, NW.	930	1¼	30	.....	
Newark	940	8–6	600	125	
Meade County:					
Fort Meade	1,450	.....	12	.....	Flow from 322 feet
Sturgis (6 miles north)	750	6–3¼	Many.	15	
Meyer County:					
Rosebud Agency (26 miles northeast).	2,500	8–6	.....	+260	
Miner County:					
T. 105, R. 57	4 0	.....	Many.	.....	
T. 106, R. 56	450–465	.....	.....	.....	Nonflowing wells ard and Villas.
T. 107, R. 56	450–580	.....	Many.	.....	No flow; good pu ply; soft water.
T. 108, R. 57	884	2¼–4	60	33	Soft water; Carth well.
Do	408–450	.....	Many.	.....	No flow; soft wat
T. 108, R. 58	4 5–430	.....	Many.	.....	Do.
T. 108, R. 58, sec. 22	894	2	.....	.....	
T. 108, R. 59, sec. 1	824	1	.....	.....	
Minnehaha County:					
Sioux Falls	575	.....	.....	.....	Unsuccessful.
Moody County:					
Flandreau (5 miles southwest of).	455	.....	.....	.....	Water found in sa
Pennington County:					
Rapid City, (one-half mile southeast of).	400	.....	.....	.....	Small flow in san
Potter County:					
T. 117, R. 77, sec. 3, SW	1,770	2	12	.....	
T. 117, R. 77, sec. 21	1,604	2	60	.....	
T. 117, R. 78, sec. 6	1,761	2	.....	.....	
Gettysburg	2,130	3	.....	.....	Water to –108 fe limited supply.
Sanborn County:					
T. 105, R. 59	476	.....	.....	.....	Flow from Dako stone.
T. 105, R. 60	400–630	2	15–165	35	Flows from Bento tion and Dako stones.
T. 105, R. 61[2]	420–670	1¼–2	4–125	80	Pressure is for on
Letcher[3]	585	3–2	80	90	

[1] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, p. 181.
[2] Ibid., pp. 631–633; Mitchell folio No. 99.
[3] Ibid., pp. 631–633.

SOUTH DAKOTA—Continued.

ocation.	Depth.	Diameter.	Yield per minute.	Pressure.	Remarks.
unty—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
.62	400–490	1¼–2			Small flows from Benton formation and Dakota sandstone.
.59	625				Flow from Dakota sandstone.
.59, sec. 18[1]	701				
[2]	708	6–2¼	120		Do.
.60	580–686				Do.
.61	560–576	2			Do.
.62	689–756	1¼–2			Do.
cket [3]	725	6	1,150	130	Do.
	775		Many	125	Woonsocket mill well.
.60	530				Flow from Benton formation.
.62	792	1¼	23		Flow from Dakota sandstone.
ty:					
℄. 60	835–920	1¼–2			
℄. 61	750–800	1¼–2	15–50		
℄. 62	890–1,000	1¼–4¼	30–1,000	125–150	
℄. 63	884–1,150	1¼–4¼	30–1,200	50	Only one pressure reported.
℄. 64	970–921	2, 1¼	100, 35		
℄. 65	870–940	1¼–1¼	35–45		
℄. 60	866–937	1¼–2	Few.		
℄. 61	450–1,050	1¼–4¼	25–75	? — 87	
℄. 62	787–987	1¼–2	42–350		
℄. 63	940–980	1¼–2	40–100		
℄. 64	874–1,085	1¼–4¼	40–1,000		
℄. 65	955	1¼	60		
℄. 60	918	1¼			
℄. 61	920–960	1¼	18–40		
℄. 62	880–920	1¼–2	35–120		
ort [4]	895	4¼	600		Blaine well.
	1,008	8–4¼			
℄. 63	858–1,029	1¼–2	25–80		
℄. 64	858–965	1¼–2	45–175		
1 [4]	964	6¼–4¼	1,260	177	Town well.
	1,025	6	1,900		Hassell & Meyers well.
	960, 1,060	4¼		+87, 105	Redfield City wells, Nos. 2 and 3.
	956	4¼	300	+124	Institution for feeble-minded.
℄. 65	908, 918	1¼–2	150		
℄. 60 [4]	897, 957	4¼	370,600	122, 112	Doland town wells.
℄. 60	921–987	1¼	10–35		
℄. 61	888–968	1¼	50–110		
℄. 62	906–950	1¼–4¼	35–350		
℄. 63	850–1,052	1¼–2	20–53		
℄. 64	813–1,387	1¼–1¼	20–70		
℄. 65	890–1,029	1¼	35–65		
℄. 66	984	1¼	50		
℄. 67	870	1¼	45		
℄. 60	850–986	1¼–2	25–35		
	920	4¼	1,300		Town well.
℄. 61	873–988	1¼	21–40		
.62	863–1,012	1¼–2	25–120		
.63	855–960	1¼–2	10–200		
.64 [4]	870–1,021	1¼–8	30–306		
	925	4¼	100	60	Chicago, Milwaukee and St. Paul Railroad well and mill well, at Ashton.
	1,003	8	2,000	150	
.65	932–1,079	1¼–2	35–150	?—150	
.60	891–1,056	1¼	30–150	130	
.61	825–970	1¼	2–60		
.62	910–1,018	1¼	26–45		
.63 [4]	920–958	1¼–4¼	60–894	141, 153	
.64	993	6 4	1,300	135	
.65	943–1,019	1¼	30–60		
.66	1,016	1¼	40		
[4]	920–1,065	3–6	467–1,320	165	
lle	980	6	1,900	156	
	1,020	2	150		
.60	960	4¼			Well in Conde.
.61	920	1¼	45		
.62	950–1,170	1¼	20–30		
.63	920	2	180		
.64	900–918	1–1¼	12–84	120	
.65	918	3	278		

[1] ol. Surv. Alexandria folio No. 100: p. 2.
[2] Ibid., 18th Ann. Rept., 1897, part 4, p.
[3] Ibid., 17th Ann. Rept., 1896, part 2, pp. 631–633.
[4] Ibid., pp. 19–20.

SOUTH DAKOTA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Pressure.	Remarks.
Sully County:	*Feet.*	*Inches.*	*Gallons.*	*Pounds.*	
T. 113, R. 79, sec. 32. SE..	1,565	3-2	175	+60	Water saline.
T. 114, R. 77, sec. 11, NW.	1,717	2	85	+20	Hard water; no gas; Oneida town well.
T. 115, R. 79, sec. 3, SE...	1,645	2	20	.....	Water soft, warm gassy; Pearl Township well "No. 2."
T. 115, R. 79, sec. 28, NW. of NE.	1,781	2	65	25	Water soft, gassy; Pearl Township well "No. 1."
T. 116, R. 78, sec. 19.....	1,595	2	85	65	Water soft and gassy.
Todd County:					
Fort Randall [1].....	610	4	600	.....	
Turner County:					
Hurley (4 miles southwest).[2]	513	.....	.....	.....	
T. 99, R. 55, sec. 34, SE.[3] .	440	.....	.....	.....	
Walworth County:					
Selby.....	1,897	2-1½	17	+16	Water alkaline, warm, gassy; main flow from 1,880 feet.
Yankton County:					
T. 93, R. 54.....	450	2	80	.....	
T. 93, R. 55.....	400-521	1-3	50-350	30-49	
Yankton (R. 55-56)[4].....	493	8	3,000	52	Excelsior mill; flow decreasing.
Fountain mills.....	600	6	1,500	48	Flow decreasing.
City well	619	8	1,000	18	
Asylum.....	672	4½	165	10	
College Hill	524	2	2,600	27	
Near (Cement Co.)...	645	6	500	.....	5 flows.
Whiting nursery.....	521	3	350	49	
—.....	400-475	2	6-95	.....	Small wells; flow decreasing.
2 miles west.....	400	2	60	60	
T. 93, R. 57.....	530, 585	1½, 2	21	+17	
T. 94, R. 54.....	432-510	2	35-75	.....	
T. 94, R. 55.....	435-648	2	3-100	12	Some alkaline water; flow decreasing.
T. 95, R. 54.....	545, 580	1-2	8	6	
T. 95, R. 55.....	535, 554	2	Many.	.....	Several flows.
T. 95, R. 56.....	544-640	2-3	43, 65	+15	
T. 96, R. 55 [2].....	590	.....	.....	.....	
T. 96, R. 56 [2].....	700	.....	Many.	.....	No flow.
T. 96, R. 57.....	505	2	5	.....	Hard water; flow ceased.

[1] Record, U. S. Geol. Surv., 17th Ann. Rept., 1896, part 2, p. 58.
[2] U. S. Geol. Surv. Parker folio No. 97.
[3] Ibid., Water-Sup. and Irr. Paper, No. 34.
[4] Record, ibid., 17th Ann. Rept., 1896, part 2, pp. 53, 58.

PUBLICATIONS RELATING TO DEEP BORINGS IN SOUTH DAKOTA.

Report on Irrigation, 52d Congress, 1st session, Senate Ex. Doc. No. 41, part 2, pp. 40-65, Washington, 1893.

Preliminary report on the artesian waters of a portion of the Dakotas, by N. H. Darton: United States Geological Survey, Seventeenth Annual Report, 1895-96, part 2, pp. 609-694, Washington, 1896.

New development in well boring and irrigation in South Dakota, by N. H. Darton: United States Geological Survey, Eighteenth Annual Report, 1896-97, part 4, pp. 567-615, Washington, 1897.

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United States Geological Survey, Olivet, Parker, Mitchell, and Alexandria folios (Nos. 96, 97, 99, and 100).

Preliminary report on the geology and underground water resources of the Central Great Plains, by N. H. Darton: United States Geological Survey Professional Paper No. 32, Washington, 1905.

TENNESSEE.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Benton County:					
Eva	727	6	5	−19	
Cheatham County:					
Kingston Springs	1,000				Unsuccessful.
Coffee County:					
Tullahoma	700				Oil well.
Crockett County:					
Bells	1,100				Prospect well; unsuccessful.
Crockett Mills	+900	3		No flow.	Abandoned.
Do	420	3	Many.	−30	
Dickson County:					
Dull (2 miles from)	565	4¼			3 oil wells.
Do	2,000	4¼			Oil well.
Dyer County:					
Dyersburg[1]	600		140	Flows.	Do.
Do	600		130		Do.
Do	591	6	100	+11	
Fentress County:					
Little Crab[2]	2,185				For oil; not found in paying quantities.
Hamilton County:					
Chattanooga	600	10–8	50	−45	
Hardin County:					
Lexington	700				
Saltillo	950	36–6	Many.	Flows.	Sulphur; temp., 45°; bored in 1830.
Knox County:					
Knoxville	2,100				Temp., 57°.
Lawrence County:					
Iron City	400	12			For oil or gas.
Do	480				For gas; not in use.
Morgan County:					
Rugby					Several wells for oil.
Obion County:					
Rives	500			−30	
Overton County:					
Livingston (just southwest).[3]	2,080				For oil.
Putnam County:					
Cookeville (2 miles southwest).[3]	1,990				Do.
Cookeville (8 miles northeast).[3]	1,549				Do.
Scott County:					
Elgin (2½ miles northwest).[3]					Do.
Glen Mary (2 miles west).[3]	1,236–1,340				Oil wells; several others in Scott County.
Do	600				
Helenwood (?)	1,500				For oil; unsuccessful.
Shelby County:					
Memphis	450–400	8–6	200–100		Several wells.
Do.[4]	+1,156				
Do	3,000–2,000				Several wells for oil; abandoned.
Union County: (?)					
Hurricane Creek[1]	530				Oil well.

[1] Tenn. Com. Ag. Oil Region Rept., 1877, pp. 54, 73.
[2] Record, U. S. Geol. Surv. Folio No. 53, pp. 4–5.
[3] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 3, pp. 699–700.
[4] Tenn. State Board of Health Bull., vol. 5, 1890, pp. 98–106.

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"Oil region," Tennessee: Commissioner of Agriculture Report, 1877.
Tennessee State Board of Health Bulletin, volume 5, 1890.
United States Geological Survey Folio No. 53, by M. R. Campbell, 1899.

TEXAS.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Anderson County:					
Palestine	650	6	Few.	−200	
Palestine (1½ miles)	400–444	8–6	121	No flow.	Several wells.
Do	560	6	100	− 80	
Angelina County:					
Burke	500				Salt water; abandon
Lufkin	1,300				No water; abandone
Archer County:					
Archer City	550	6	Few.	− 50	Alkali water.
Do.[1]	736			No flow.	
Do	500				Salt water only.
Atascosa County:					
Tobey	1,200–1,300				
Bastrop County:					
Bastrop	+900				No water.
Bell County:					
Belton (9 miles west)	700			Flows.	
Belton (10 miles southeast).	1,800		Many.	Flows.	
Belton (2 miles northeast).	1,000			Flows.	
Belton (19 miles west)	530			Flows.	
Belton (9 miles southwest).	772		70	Flows.	
Belton[2]	975	4	173.6	Flows.	Soft water.
Belton (1 mile southwest).	1,060		347	Flows.	Do.
Belton (1 mile south)	1,000			Flows.	
Holland (10 miles south).	1,800		10	Flows.	Salt water.
Killeen	606			− 60	
Rogers	+1,600			Flows.	
Salado (5 miles southeast).	412			−397	
Temple (1 mile west)	1,850		Many.	Flows.	Temp., 91°.
Do	1,800		Few.	Flows.	
Troy	1,472	8		Flows.	Soft water.
Do	1,474		14	Flows.	
Do	1,464		243	Flows.	Do.
Youngsport	404		1	Flows.	
Do	417		¼	Flows.	
Youngsport (1½ miles east).	433		¼	Flows.	
Youngsport (one-half mile north).	444		1	Flows.	
Bexar County:					
Aul[4]	673			− 4	
Fort Sam Houston	726		200	− 5	Water-bearing beds a and 398 feet; wate 398 feet being salty.
San Antonio[4]	822–1,200		55–200		Numerous wells.
Do	1,250				
Do	465		55		
San Antonio (1 mile west)	835		55		
San Antonio					
Do	870		861		
San Antonio (3 miles southeast).	1,100				Hot sulphur water.
San Antonio (3 miles south).	1,900		555		
San Antonio (6 miles southeast).	2,215				Water at 1,800 feet.
San Antonio (2 miles south).	1,900		555	84	
San Antonio	500				Several wells.
Do	650–715		500–700		Do.
San Antonio (2½ miles northwest).	540				
San Antonio	630				
Do	750–780		1,000		Do.
Do	450				
Do	657		250		Do.
San Antonio (3 miles north).	583			− 50	
Bosque County:					
Cayote (3 miles northeast).	439			No flow.	
Clifton	640		170	Flows.	
Do	700		Many.		Temp., 70°.

[1] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 262.

[2] Record, Artesian waters of Texas west of the 97th meridian, by R. T. Hill: 52d Cong., 1st sess., Senate Ex. Doc. No. 41, part 3, 1893 p. 116.

[3] Record, U. S. Geol. Surv., 18th Ann. R 1896–97, part 2, p. 272.

[4] Ibid., pp. 290–297.

TENNESSEE.

ocation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
unty:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
.....	727	6	5	−19	
County:					
on Springs.....	1,000	.....	.....	.....	Unsuccessful.
nty:					
oma	700	.....	.....	.....	Oil well.
ounty:					
.....	1,100	.....	.....	.....	Prospect well; unsuccessful.
tt Mills.....	+900	3	.....	No flow.	Abandoned.
.....	420	3	Many.	−30	
ounty:					
miles from).....	565	4¼	.....	.....	3 oil wells.
.....	2,000	4¼	.....	.....	Oil well.
ty:					
urg[1].....	600	.....	140	Flows.	Do.
.....	600	.....	130	.....	Do.
.....	591	6	100	+11	
ounty:					
Crab[2].....	2,185	.....	.....	.....	For oil; not found in paying quantities.
County:					
nooga	600	10–8	50	−45	
unty:					
ton.....	700	.....	.....	.....	
.....	950	36–6	Many.	Flows.	Sulphur; temp., 45°; bored in 1830.
ity:					
ille.....	2,100	.....	.....	.....	Temp., 57°.
County:					
ty	400	12	.....	.....	For oil or gas.
.....	480	.....	.....	.....	For gas; not in use.
unty:					
.....	.....	.....	.....	.....	Several wells for oil.
nty:					
.....	500	.....	.....	−30	
ounty:					
ston (just south-.[2]	2,080	.....	.....	.....	For oil.
ounty:					
ille (2 miles west).[2]	1,990	.....	.....	.....	Do.
ille (8 miles east).[2]	1,549	.....	.....	.....	Do.
ty:					
(2½ miles north-.[2]	.....	.....	.....	.....	Do.
Mary (2 miles .[3]	1,236–1,340	.....	.....	.....	Oil wells; several others in Scott County.
.....	600	.....	.....	.....	
vood (?).....	1,500	.....	.....	.....	For oil; unsuccessful.
unty:					
ils	450–400	8–6	200–100	.....	Several wells.
.[4].....	+1,156	.....	.....	.....	
.....	3,000–2,000	.....	.....	.....	Several wells for oil; abandoned.
nty: (?)					
ane Creek[1].....	530	.....	.....	.....	Oil well.

om. Ag. Oil Region Rept., 1877, pp. 54, 75.
U. S. Geol. Surv. Folio No. 53, pp. 4, 5.
eol. Surv., 17th Ann. Rept., 1895–96, 699–700.
[4] Tenn. State Board of Health Bull., vol. 5, 1890, pp. 98–106.

ICATIONS RELATING TO DEEP BORINGS IN TENNESSEE.

States Geological Survey, Seventeenth Annual Report, 1896, parts 2 and 3.
egion," Tennessee: Commissioner of Agriculture Report, 1877.
see State Board of Health Bulletin, volume 5, 1890.
States Geological Survey Folio No. 53, by M. R. Campbell, 1899.

TEXAS.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Anderson County:					
Palestine	650	6	Few.	−200	
Palestine (1¼ miles)	400–444	8–6	121	No flow.	Several wells.
Do	560	6	100	− 80	
Angelina County:					
Burke	500				Salt water; abando
Lufkin	1,300				No water; abandon
Archer County:					
Archer City	550	6	Few.	− 50	Alkali water.
Do.[1]	736			No flow.	
Do	500				Salt water only.
Atascosa County:					
Tobey	1,200–1,300				
Bastrop County:					
Bastrop	+900				No water.
Bell County:					
Belton (9 miles west)	700			Flows.	
Belton (10 miles southeast).	1,800		Many.	Flows.	
Belton (2 miles northeast).	1,000			Flows.	
Belton (19 miles west)	530			Flows.	
Belton (9 miles southwest).	772		70	Flows.	
Belton[2]	975	4	173.6	Flows.	Soft water.
Belton (1 mile southwest).	1,060		347	Flows.	Do.
Belton (1 mile south)	1,000			Flows.	
Holland (10 miles south).	1,800		10	Flows.	Salt water.
Killeen	606			− 60	
Rogers	+1,600			Flows.	
Salado (5 miles southeast).	412			−397	
Temple (1 mile west)	1,850		Many.	Flows.	Temp., 91°.
Do	1,800		Few.	Flows.	
Troy	1,472	8		Flows.	Soft water.
Do	1,474		14	Flows.	
Do	1,464		243	Flows.	Do.
Youngsport	404		1	Flows.	
Do	417		½	Flows.	
Youngsport (1¼ miles east).	433		¼	Flows.	
Youngsport (one-half mile north).	444		1	Flows.	
Bexar County:					
Aul[3]	673			− 4	
Fort Sam Houston	726		200	− 5	Water-bearing beds and 398 feet; wa 398 feet being salt
San Antonio[4]	822–1,200		55–200		Numerous wells.
Do	1,250				
Do	465		55		
San Antonio (1 mile west)	835		55		
San Antonio					
Do	870		861		
San Antonio (3 miles southeast).	1,100				Hot sulphur water.
San Antonio (3 miles south).	1,900		555		
San Antonio (6 miles southeast).	2,215				Water at 1,800 feet.
San Antonio (2 miles south).	1,900		555	− 84	
San Antonio	500				Several wells.
Do	650–715		500–700		Do.
San Antonio (2½ miles northwest).	540				
San Antonio	630				
Do	750–780		1,000		Do.
Do	450				
Do	657		250		Do.
San Antonio (3 miles north).	583			− 50	
Bosque County:					
Cayote (3 miles northeast).	439			No flow.	
Clifton	640		170	Flows.	
Do	700		Many.		Temp., 70°.

[1] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 262.

[2] Record, Artesian waters of Texas west of the 97th meridian, by R. T. Hill: 52d Cong., 1st sess., Senate Ex. Doc. No. 41, part 3, 1893 p. 116.

[3] Record, U. S. Geol. Surv., 18th Ann. I 1896–97, part 2, p. 272.

[4] Ibid., pp. 290–297.

TEXAS—Continued.

n.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
es north) ..	662	.....	220	Flows.	Temp., 84°; soft water.
e west)	715	.....	60	Flows.	Soft water.
lles north).	670	.....	170	Flows.	
iles south-	840	.....	170	Flows.	
es west)....	612	.....	.....	Flows.	Do.
e west).....	687	.....	.....	Flows.	Do.
.....	700	.....	Many.	.....	Temp., 70°.
ee-fourths	700	.....	11	Flows.	Soft water.
east)	1,000	.....	Many.	Flows.	
.....	780	.....	34	Flows.	
.....	529	.....	30	Flows.	
le north)...	475	.....	.....	Flows.	Do.
ee-fourths	460	.....	10	Flows.	
ourth mile	430	.....	68	Flows.	Do.
lles north).	735	.....	123	Flows.	Do.
.....	550–630	.....	.....	Flows.	Several wells.
iles west)..	564	.....	60	+ 20	Soft water.
.....	400	.....	½	Flows.	
ree-fourths	600	.....	800	Flows.	Do.
.....	625	.....	150	Flows.	Slightly brackish.
niles west).	609	.....	200	.....	
.....	525	.....	.....	Flows.	
.....	450–580	.....	25–45	Flows.	Several wells; soft water.
miles east).	850	.....	16	Flows.	
miles east).	875	.....	.....	− 42	Soft water.
.....	600	.....	100	Flows.	Do.
.....	580–620	.....	20–150	Flow.	Several wells; soft water.
ile south-	575	.....	170	Flows.	Soft water.
.....	800	.....	50	Flows.	
les east) ...	780	.....	40	Flows.	
iles east) ..	501	.....	100	Flows.	
les south-	622	.....	.....	No flow.	Do.
.....	805	.....	.....	Flows.	
(5 miles	870	.....	.....	Flows.	Do.
(1 mile	706	.....	.....	Flows.	
(5 miles	877	.....	.....	Flows.	Do.
iles north h of Mill	425	2	.....	− 2	Abandoned.
.....	1,200	.....	.....	− 75	
.....	536	3½	.....	.....	Salt water at 500 feet.
.....	800	.....	.....	− 20	Once flowed.
.....	1,200	5	.....	− 60	Salty water; used for stock.
.....	550	.....	.....	.....	
s north) ...	502	2	70	.....	
.....	600–1,500	.....	.....	.....	
ileswest)[3]	600	.....	.....	.....	Strong pressure of gas at 600 feet; large flow of water with small quantities of oil.
hwest of)[4]..	1,160	.....	.....	.....	Herndon well; rock salt from 587 to 1,160 feet; considerable quantities of sulphur water; no traces of oil.
.....	1,097	.....	.....	.....	Well No. 1 of the J. M. Guffey Petroleum Co.
iwest of)[4]..	1,230	.....	.....	.....	Damond Mound Oil and Pipe Line Company's well.
.....	650	.....	.....	.....	
.....	1,500	.....	.....	.....	Prospect for oil; artesian water stratum at 1,000 feet.
.....	1,070	4	215	Flows.	
.....	1,000	.....	.....	.....	
.....	1,100	8	694	Flows.	

ong., 1st sess., Senate Ex. Doc.

v. Bull. No. 212, p. 41.

[3] Record, ibid., p. 40.

[4] Ibid., pp. 37–39.

TEXAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks
Brazoria County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Velasco (3¼ miles southwest).	745	.....	.....	.....	Limestone at where strong was struck, abandonment
Velasco	1,060	.....	20–50	Flows.	7 wells.
Brown County:					
Brownwood (northeast of).	1,900	.....	.....	.....	Oil borings; som
Brownwood	1,938	10–6	32	+ 74	
Do	1,558	.....	.....	.....	Failure.
Do	1,803	.....	.....	.....	Do.
Menardville (near)	1,100	.....	.....	.....	Found water, etc. now caved in.
Burleson County:					
Bryan (16 miles south)	870	2	22	Flows.	
Bryan (12 miles from)	835	2	35	+ 30	Temp., 85°.
Do	635	2	22	+ 25	Temp., 76°.
Do	550	7	15	+ 20	Do.
Myers	440	1–2	2	.....	Temp., 60°.
Do	860	4–2	30	+ 20	Temp., 90°.
Calhoun County:					
O'Connorsport[1]	1,484	.....	.....	.....	
Do.[1]	494	.....	.....	.....	
Port Lavaca (8 miles)	402	.....	25	Flows.	
Port Lavaca (8 miles southeast).	440	.....	5	Flows.	
Port Lavaca (25 miles southeast).	530	4	40	Flows.	
Port Lavaca (24 miles southeast).	1,484	.....	40	Flows.	3 wells.
Callahan County:					
Baird	415	8	.....	.....	Abandoned.
Cameron County:					
La Parra ranch[2]	1,500	.....	.....	.....	For oil; abandon
——	490–1,364	.....	8–1,000	Flow.	36 wells.
Camp County:					
Pittsburg	1,600	.....	Many.	.....	
Do	1,860	6–4	Many.	− 10	Water from 200 fe
Do	1,860	.....	140	− 8	
Carson County:					
Panhandle City	600	.....	.....	.....	Unsuccessful.
Chambers County:					
High Island[3]	610	.....	.....	.....	Abandoned.
Do.[3]	1,000	.....	.....	.....	Oil at 504 feet, quantity.
Turtle Bayou	850	4	139	Flows.	
Do	900	4	.....	.....	
Wallisville	400	.....	70	.....	
Winnie (3 miles north)[4]	1,510	.....	.....	.....	
Cherokee County:					
Circle	600	.....	.....	.....	Test for oil.
Jacksonville	2400	.....	.....	.....	Choked with sand
Morton	600	.....	.....	.....	Abandoned.
Rusk	620	.....	.....	.....	Do.
Wells	600	.....	.....	.....	Unsuccessful.
Childress County:					
Childress	1,263	.....	.....	.....	Impregnated wi and gypsum.
Do	415	5	35	400	
Collin County.					
Celina	470	.....	7.7	- 145	Soft water.
Celina (1 mile west)	400	.....	.....	- 100	Do.
Frankfort (2 miles southwest).	442	.....	.....	- 50	Salty water.
Lebanon	400	.....	Many.	- 100	
McKinney	1,860	.....	21	− 70	Soft water.
Prosper	470	.....	Many.	No flow.	Do.
Prosper (three-fourths mile east).	660	.....	4	−244	Do.
Colorado County:					
Columbus	807	.....	.....	Flows.	
Concho County:					
Eden	987	.....	7	Flows.	Salty water.
Do	800	.....	.....	.....	Oily water; aband
Cooke County:					
Gainesville	1,250	.....	.....	− 40	
Do	850	.....	243	- 10	
Do	480	.....	.....	- 40	
Do	405	.....	69	No flow.	
Do	632	.....	Many.	7	

[1] U. S. Geol. Surv. Bull. No. 212, pp. 34-35.
[2] Ibid., p. 19.
[3] Record, U. S. Geol. Surv. Bull. No. 212,
[4] Ibid., p. 61.

TEXAS—Continued.

n.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
ontinued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
.....	700	.....	.....	− 30	
.....	850	.....	6	.....	
.....	426	.....	100	Flows.	Soft water.
niles north-	426	.....	1	.....	Do.
.....	1,865	.....	.....	−100	Brackish water.
e (4 miles	500	.....	Many.	No flow.	Salty water.
.....	1,875	.....	.....	−475	
les east)....	940	.....	Many.	− 50	Soft water.
.....	500–550	6	2–20	Flow.	Several wells.
.....	700	.....	175	.....	
.....	475	.....	.....	No flow.	Soft water.
niles west).	612	.....	.....	.....	Do.
niles south-	558	.....	4	Flows.	
.....	500	.....	.....	.....	
iles north-	697	.....	.....	− 5	Mineral water.
iles north-	500	.....	.....	No flow.	Soft water.
.....	590	.....	.....	Flows.	
.....	900	.....	680	− 13	
es south)...	423	.....	.....	− 85	Saline water.
(19 miles	750	.....	Many.	−300	Soft water.
e east)	850	.....	70	Flow.	2 wells.
iles west-	+400	.....	Many.	Flows.	
.....	790–1,000	.....	Many.	Flows.	Numerous wells.
.....	718	.....	.....	Flows.	Much soda in water.
.....	700	.....	12	Flows.	
Park)	672	.....	15	Flows.	
.....	±2,500	.....	.....	.....	
e south)....	850	.....	70	Flow.	2 wells.
iles west-	±400	.....	Many.	Flows.	
.....	417	.....	800	+ 35	Soft water.
.....	970	.....	.....	Flow.	Do.
.....	1,057	.....	.....	Flows.	Do.
me Station utheast).	685	.....	.....	No flow.	Very salty water.
ne Station..	1,230	.....	20	− 40	Mineral water.
s (4 miles	±468	.....	.....	− 25	
.....	415	.....	.....	− 25	
iles east)...	500	.....	.....	Flows.	Soft water.
.....	1,176	.....	.....	Flows.	
.....	460	.....	.....	+ 15	
.....	550	6	6	+ 20	
.....	600	.....	Few.	.....	
.....	620	.....	8	Flows.	
.....	600	.....	.....	Flows.	
.....	606	.....	28	Flows.	
.....	592	6–4	12	.....	
les south)..	450	.....	.....	No flow.	
.....	937	.....	17	− 25	Do.
st).....	476	.....	.....	− 33	
.....	400–600	.....	40–50	Flows.	Several wells.
e-half mile	505	.....	.....	− 16	
es south)...	447	.....	3	Flows.	Soft water.
ear)[2].....	1,200	.....	.....	.....	Small quantities of oil at various depths.
gs (near) ..	400–690	4–10	100–1,400	Flows.	Several wells.
.....	1,680	8	.....	− 25	Salt water.
.....	500	.....	.....	.....	Abandoned.
.....	1,300	6	.....	No flow.	Salt water.
.....	400	.....	.....	Flows.	Mineral water.
.....	830	8	.....	.....	Abandoned.
.....	400	.....	Many.	No flow.	2 wells.
.....	450	.....	Many.	No flow.	Do.

Cong., 1st sess., *Senate Ex. Doc.*

[2] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, pp. 268, 269.

v. Bull. No. 212, p. 19.

TEXAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Ellis County:					
Boyce (1½ miles west)	981		1½	Flows.	Soft water.
Do	975			Flows.	Do.
Ferris	1,360		89	Flows.	
Forreston	400				No water.
Italy	1,400		½	− 10	Soft water.
Midlothian	464			−200	
Milford	2,018			Flows.	Mineral water.?
Mountain Peak (three-fourths mile southwest).	435		Many.	No flow.	Soft water.
Palmer	1,154		+9	Flows.	Do.
Do	1,154			Flows.	Do.
Do	1,178		83	Flows.	Do.
Waxahachie	990			Flows.?	
Do	1,700			− 15	Do.
Waxahachie (6 miles southwest).	700			−125	
El Paso County:					
Eagleflat	600				No water.
El Paso (northwest of)	800				In granite; no wate
El Paso (10 miles northeast).[1]	621			−215	
El Paso (5 miles northeast).[2]	2,285			−172?	Many similar but lower wells in vicinity; principa horizon is at 230 f water below 450 f
El Paso (1½ miles east)[1]	1,693			− 15?	For artesian wate successful.
El Paso (8 miles northeast).[3]	450				
El Paso (16 miles east)[2]	605				Abandoned.
El Paso (20 miles northeast).[3]	450				
El Paso (25 miles southeast).[3]	500			−410	
El Paso (35 miles southeast.)[4]	500				Dry.
El Paso (40 miles northeast).[3]	850				Do.
Finlay[4]	1,080	8			Bad water at 39 abandoned.
Fort Bliss Station	403	4½	Many.	−130	
Fort Hancock[3]	600				Abandoned; wate for boiler use.
Haskell	2,029	12-7½	Few.	No flow.	
Kent (35 miles northwest).[3]	916 and 800				2 wells; dry.
Kent (30 miles north)[3]	700				Dry.
Kent (7 miles north)[3]	515				Do.
Kent	400				Do.
Lasca (near)[3]	1,100			−600	Well abandoned; water at 600 feet.
Plateau[3]	547				Dry.
Plateau (3 miles east)[3]	600			−260	Abandoned.
Sierra Blanca[5]	943	5⅝	Many.	No flow.	Bad water.
Do.[3]	1,350				Well abandoned; unfit for boiler us
Torbert	1,100	8-5½			Abandoned; small a of fair water at 6
Torrence (near)	850	18-10	70	−357	At milepost 199.
Toyah (60 miles northwest).[3]	546			−260	
Van Horn	600	5½		−500	Several wells.
Erath County:					
Dublin	400			8	
Thurber[6]	3,050			No flow.	
Falls County:					
Marlin	3,350		140	+322	Temp., 147°.
Fannin County:					
Bonham	+400				
Do	+400				
Do	1,500				No water.
Honeygrove	1,700		Many.		Strong mineral wat
Do	1,650		Many.	− 50	Do.
Do	1,500				

[1] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 297.
[2] Record, Texas Univ. Mineral Survey Bull. No. 9, 1904, pp. 96-97.
[3] *Texas Univ. Mineral Survey Bull. No. 9, 1904, pp. 109-111.*
[4] Analysis, 51st Cong., 1st sess., Senate E No. 222, p. 272.
[5] Record, ibid., p. 296.
[6] Ibid., p. 270.

TEXAS—Continued.

on.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
.....	1,000	.....	.....	−300	Salty water; not in use.
.....	1,200	.....	.....	No flow.	
.....	.....	.....	.....	.....	
.....	1,033	.....	.....	.....	Never completed.
ty:					
.....	+910	.....	300	Flows.	
.....	600–1,550	3–4	.....	Flows.	Several wells.
.....	1,550	8–4	104	+ 9	
.....	1,760	.....	7	Flows.	
y:					
on	400	.....	.....	No flow.	Large supply of water.
ty:					
.....	.....	.....	.....	.....	Not completed.
miles north-	1,350	.....	.....	.....	
miles north-	1,200	.....	.....	.....	Sulphur water at 800 feet.
.....	.....	.....	.....	.....	Salt water.
.....	540	.....	Many.	− 35	
.....	600	.....	15	Flows.	
.....	400	.....	30	Flows.	
.....	650	.....	30	Flows.	
.....	620	.....	.....	− 20	
miles east)	.....	.....	.....	Flows.	Several wells.
miles south-	(?)	.....	.....	.....	
ty:					
.....	875–950	9	310	22	Numerous wells; temp., 75°–78°.
.....	726–868	5–7	.....	.....	13 wells.
.....	600	3	14	Flows.	
.....	624	3	40	Flows.	
½ miles west)	700	3	34.7	Flows.	
(one-fourth	588	1	.....	Flows.	
.					
.....	575	3	50	Flows.	Temp., 78½°.
.....	3,070	22–6	Many.	Flows.	Brackish water at various depths to bottom.
.....	1,346	.....	400	Flows.	Salty water.
.....	810–973	.....	Many.	Flows.	Several wells; water too salty.
¼ miles west)	1,365	.....	250	Flows.	Temp., 84°.
.....	480	3	52	+ 16	Temp., 60°±.
.....	726	.....	66	Flows.	Temp., 77°; many wells in vicinity.
(1¼ miles	710	.....	100	Flows.	Temp., 77°.
).					
.....	768	.....	48	Flows.	Temp., 78°.
.....	700–750	3–4	20–75	Flows.	3 wells.
.....	410–750	.....	.....	.....	6 wells.
ston	575–1,590	3	70 each.	Flows.	Several wells.
.....	725	.....	+104	+ 16	
.....	900	.....	+104	+ 16	
:					
h[5]	1,100	.....	.....	− 55	
:					
nile south)[6]	1,800	2½	.....	.....	Abandoned.
miles west)	+500	.....	Many.	Flows.	Pure water.
.....	632	.....	.....	.....	Fine water.
.....	915	.....	.....	.....	
.....	2,500	.....	Many.	− 40	
.....	660	.....	.....	.....	Several wells.
miles north)	480	.....	.....	No flow.	
.....	+800	.....	.....	No flow.	
.....	500	.....	80	.....	Lignitic.
.....	830	.....	.....	To surface.	
miles north)	999	.....	Many.	Flows.	
ity:					
.....	810	.....	.....	+180	Good water.
ion	550	6	.....	.....	4 layers of salt water; abandoned.

tas Geol. Surv. 4th Ann. Rept.,

ibid., pp. 87–101. U. S. Geol. Rept., 1899–1900, part 7, pp. 102–

[4] Analysis, etc., ibid., pp. 102–103.

[5] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896–97, part 2, p. 272.

[6] Ibid., 21st Ann. Rept., 1899–1900, part 7, p. 197.

[7] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 265.

TEXAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Hamilton County:					
Hamilton	425				Water only at 350 feet to −8 feet.
Hico	1,365	12		−125	Water at 210, 300, 600, and 900 feet.
Do	1,200			No flow.	
Lanham	470				Abandoned.
Do	500				Do.
Do	600				
Hardin County:					
Batson	885	4			Produces 50 barrels of oil daily.
Saratoga [1]	995				
Do. [2]	700				Libbie well.
Do. [2]	600				Conroy well.
Do. [2]	1,700				Texas geyser well.
Saratoga (3 miles west) [3]	958				Some oil and 2 streams of hot water encountered; the first stream had temperature of 100° and was found at 938 feet; the other stream, at 950 feet, was hotter.
Sour Lake (3 miles northeast). [4]	1,284				
Sour Lake [5]	1,400				Oil and gas; some salt water.
Do. [6]	725, 680				
Do. [7]	1,500				Oil-bearing horizons at 960 feet and 1,460 feet; hot sulphur water encountered at several levels.
Do. [8]	1,000–2,000				Several wells; unproductive.
Harris County:					
Cedar Bayou	558	3			
Do	600	3		Flows.	
Do	727	3	5	Flows.	Temp., 76°.
Do	610	3	30		Do.
Houston	1,006				
Do	493	8	120	Flows.	
Do	564	8	130	Flows.	
Do	850	5	200	Flows.	
Do	500 or less.			Flows.	Fine water.
Do	700				
Houston (3 miles from)	600		42		Temp., 70.
Houston	2,025	8–4			Large supply of water; gas at 1,600 feet.
Humble	600	3¼	50	Flows.	Fresh water.
Do	1,000	6–2¼			Prospect for oil; unsuccessful.
Do	990	11¼–6			Produces 100 barrels of oil daily; gas present in increasing amounts below 600 feet.
Do	1,500				Prospect for oil; little gas at 600 feet; water-bearing beds 600 to 650 feet and 1,150 to 1,200 feet.
Laporte	454	3	41	Flows.	
Do	440	3	80	Flows.	
Strong Junction	450	3	48	+ 9	
Zimbi [9]	480				No water; abandoned.
Do	520				Do.
Harrison County:					
Marshall	1,000			No flow.	
Marshall (9 miles south)	450	6–4		− 75	Very slightly salty.
Hartley County:					
Hartley	410	5	17		
Hays County:					
San Marcos [10]	1,490		6	Flows.	Waters at 128, 191, 652, 1,178, 1,291, 1,345, and 1,475 feet.
Hidalgo County:					
Brownville (50 miles northwest).	70			No flow.	
Hidalgo	700			+ 100	
"Magueyes"					Test well.
Valeo	1,004	8			No water below.
——	438–484		10–75	Flows.	5 wells.

[1] Record, U. S. Geol. Surv. Bull. No. 212, pp. 120–121.
[2] U. S. Geol. Surv. Bull. No. 212, p. 121.
[3] Record, ibid., p. 59.
[4] Ibid., p. 60.
[5] *Partial record, ibid., p. 116.*
[6] *Record, ibid., p. 117.*
[7] U. S. Geol. Surv. Bull. No. 212, pp. 117–118.
[8] Ibid., p. 118.
[9] Record, etc., Texas Geol. Surv. 4th Ann. Rept., 1892, p. 107.
[10] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896–97, pp. 287–290.

TEXAS—Continued.

n.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
les north)	446	.....	20	−160	
.....	486	.....	Several.	−186	
.....	600	.....	Few.	Flows.	
.....	800	.....	Several.	Flows.	
s east)	532	.....	.....	−200	
.....	1,800	.....	.....	Flows.	
.....	1,762	.....	34.7	Flows.	
.....	500	.....	.....	.....	Failure.
.....	3,166	.....	.....	Flows.	
.....	1,800	.....	.....	Flows.	
.....	1,680	.....	160	+ 35	
.....	1,575	.....	.....	+ 40	
.....	1,000	.....	139	Flows.	
.....	438	.....	.....	430	
south)	415	.....	.....	No flow.	Soft water.
ngs	1,514	6–4	.....	.....	Small supply of water.
.....	630	5–3	Many.	−190	
.....	1,065	3	80	−105	Water tastes like alum.
.....	603	7	.....	.....	Salt water at 300 feet; abandoned.
.....	2,300	.....	.....	.....	
.....	400	.....	$\frac{1}{48}$	−400	Soft water.
.....	1,370	.....	.....	.....	Evidences of oil at 852 feet; artesian water at 1,000 feet.
iles south-	402	.....	4	Flows.	
les south)	800	.....	.....	Flows.	
.....	1,245	5¼–3	Many.	No flow.	
7¼ miles	1,515	6–4	.....	.....	For oil; unsuccessful; water at 220 and 260 feet; gas at 240 and 400 feet.
spindletop	930	.....	.....	.....	Oil well.
.....	1,006	.....	.....	.....	Do.
.....	765–1,139	.....	.....	.....	280 producing wells.
ar Spindle-	1,400–2,075	.....	.....	.....	11 wells; no oil.
.....	800–2,315	.....	.....	.....	52 dry and abandoned wells.
.....	1,400	.....	.....	.....	Few small pockets of oil.
.....	+800	5	.....	Flows.	Mineral water; temp., 80°.
.....	1,260	.....	.....	.....	Abandoned.
(3 miles	1,486	.....	.....	.....	Do.
.....	1,500	.....	.....	Flows.	
ile west)	500	.....	.....	No flow.	Soft water.
iles west)	465	.....	Many.	No flow.	Do.
.....	970–1,003	.....	70	−40 to −70	Many wells.
iles south)	520	.....	Many.	No flow.	Soft water.
iles south-	568	.....	.....	−168	Do.
iles south-	420	.....	Many.	−160	Do.
iles north-	424	.....	Many.	−271	
iles south)	500	.....	15	Flows.	Do.
¼ miles	618	.....	18	Flows.	
¼ miles	585	.....	65	Flows.	Good water.
¼ miles	548	.....	12	Flows.	Soft water.
es south)	420	.....	Many.	No flow.	Do.
one-half	590	.....	45	.....	Do.
one-half west).	602	.....	22	Flows.	Do.

eol. Surv. Bull. No. 212, pp. 74–75.
.
v. Bull. No. 212, pp. 77–85.
pp. 88–102.

[5] U. S. Geol. Surv. Bull. No. 212, pp. 103–104.
[6] Ibid., p. 126.
[7] Record, ibid., p. 112.
[8] Ibid., p. 113.

TEXAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Johnson County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Joshua (3 miles west)	525			No flow.	Soft water.
Joshua (6 miles northwest).	424			−189	
Keene	750			−300	Do.
Rendon (2 miles north)	535		Many.	No flow.	Do.
Riovista (1 mile northeast).	460		Many.	No flow.	Do.
Riovista (3 miles east)	540			−176	Do.
Kearnes County:					
Kearnes	1,800				Failure.
Kaufman County:					
Kaufman	450				Do.
Kaufman (1 mile northwest).	600				Do.
Terrell[1]	2,200	8	70	− 50	Good water.
Kerr County:					
Kerrville	1,325			− 75	Good water at 750 feet.
Kerrville (9½ miles northeast).[2]	1,100		Several.	− 55	Granite below 180 feet.
Kinney County:					
Austin (near)	400				Several wells.
Brackettville (7 miles from).[3]	404		Several.		
Spofford Junction	1,700				Failure.
Lamar County:					
Paris	444				Abandoned.
Do	1,350		Many.	− 5	
Lasalle County:					
Cotulla[4]	825			Flows.	Bad water.
Do	1,010		55.5		
Do	852				
Do	800		2	Flows.	Do.
Do	1,008		Many.	+ 6	Temp., 86° F.; alkaline-saline water.
Cotulla (8 miles south)	600			−100	Bad water.
Lavaca County:					
Hallettsville	300–560			Flow.	
Liberty County:					
Dayton[5]	1,900				J. M. Guffey Petroleum Co.'s well.
Do.[5]	500–1,000				Taylor-Dayton Co.'s wells.
Do.[5]	1,200				Rock salt from 800 to 1,200 feet.
Keno	700				No water below 90 feet; abandoned.
Stilson[5]	500 (nearly)				2 wells.
Limestone County:					
Island[6]	+800				Dry.
Wexia	1,333	4¼			Oil or gas prospect: abandoned: some water at 512 feet.
Llano County:					
Llano (9 miles southeast)	500			+ 2	Coal prospect; abandoned.
McLennan County:					
Bruceville	1,560	6		+125	
Do	1,565		139	Flows.	Soft water: temp., 95°.
China Springs	1,380			Flows.	Another flow at 800 feet; temp., 102°.
Do	1,100		40	Flow.	2 (?) wells.
Crawford (4 miles west)	1,000		31		Soft water.
Do	1,040		31		Do.
Do	945		140		Temp., 72° F.; 2 wells.
Do	1,060		50		Soft water.
Eddy	1,565		208	Flows.	Do.
Farr (2 miles south)	1,065		10	Flows.	
Harmosa	1,730		139		Soft water, temp., 103°.
Lorena	1,495		Many.	Flows.	Soft water.
Lorena (5 miles west)	760		Few.	Flows.	Salt water.
Lorena	1,495		Many.	Flows.	Soft water.
McGregor	1,030		139	− 10	Do.
Do	470			Flows.	
Do	991		348		
McGregor (5 miles west)	490		Many.	− 11	Do.
Moody	1,508		69	No flow.	Soft water.

[1] Record, Artesian waters in Texas west of 97th meridian, by R. T. Hill. 52 Cong., 1st sess., Senate Ex. Doc. No. 41, part 3, p. 99. Another authority gives 2,700 feet as depth

[2] U. S. Geol. Surv., 18th Ann. Rept., 1896–97, part 4, p. 271.

[3] Record, ibid., p. 278.

[4] Texas Geol. Surv. 2d Ann. Rept., 1891, p. 71; analysis, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 272.

[5] Record, U. S. Geol. Surv. Bull. No. 212, pp. 46–47.

[6] U. S. Geol. Surv. Bull. No. 212, p. 24.

TEXAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
McLennan County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Moody	1,300			No flow now.	
Do	1,450			− 15	
Ocee (1 mile east)	1,098	6	160	Flows.	Soft water.
South Bosque (3 miles west).	450		1		
Waco[1]	1,812–1,862	8–4	51–400	Flow.	Numerous wells; temp., 103°.
Waco (5 miles west)	1,470	4½	347	Flows.	Pure water; temp., 90°.
West	1,690		208	Flows.	
McMullen County:					
Tilden	475	4½	8	Flows.	Salty water.
Do.[2]	600				Strong flow of brackish water, with gas.
Tilden (12 miles south)[2]	900				Small flow of strong salt brine.
Marion County:					
Jefferson	802		Few.	Flows.	Sulphur water, but good.
Matagorda County:					
Bay City (10 miles east)[3]	+900				Small quantities of oil, and at 900 feet the gas became unmanageable and well was abandoned; gas not utilized.
Maverick County:					
Eagle Pass[4]	1,508				Salty water.
Do	400				Abandoned.
Medina County:					
Hondo	1,000				No water.
Do	1,500		Many.	−175	
Menard County:					
Menardville	1,175				Oil boring unsuccessful.
Milam County:					
Baileyville	800				Failure.
Baileyville (3 miles west).	831			No flow.	Water very salty.
Branchville (4 miles east).				Flows.	
Do	700			− 6	
Maysfield	1,356	4	Many.	− 34	
Thorndale	1,790				No water.
Do	3,200				Do.
Mills County:					
Goldthwaite	563	10–7		− 20	
Do	600				
Do	563	10–7		− 20	
Mitchell County:					
Colorado[5]	1,120				Several deep salt wells.
Montague County:					
Belcherville	900–1,200		70	Flow.	3 wells; soft water.
Bowie	700			−160	
Bowie (one-half mile west).	600				
Montgomery County:					
Wilburton	917				Produces 50 barrels of oil daily.
Conroe	1,236	8		Flows.	
Nacogdoches County:					
Chireno[6]	840		50	+ 10	
Nacogdoches	400		Many.		In progress.
Nacogdoches (13 miles southeast).	435	6			Water at 68 and 393 feet; oil at 212, 312, 328, and 360 feet.
Navarro County:					
Corsicana					
Corsicana (3 miles west)	2,500				
Do	2,300				
Corsicana	2,477				Several wells.
Do	1,000–1,200				Many oil wells.
Do	2,483		208	+150	Water, gas, and oil; temp., 126°.
Do	2,150		208		Oil at 1,100 feet.
Do	2,487		Many.		
Do	2,500		+194.4	+ 85	Temp., 126° f.
Do	1,035				Oil well.
Newton County:					
Call	700		Several.	Flows.	
Do	796	4	87	Flows.	

[1] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, pp. 265, 269; analysis, p. 271.
[2] U. S. Geol. Surv. Bull. No. 212, p. 18.
[3] Ibid., p. 127.
[4] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 266.
[5] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896–97, part 2, p. 265.
[6] Record, La. Geol. Surv. Rept., 1902, p. 126.

TEXAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Nueces County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Alice[1]	1,000				
Alice (near)[1]	500-750				Several wells; stro tesian flows.
Coldris	590	5 3/16-4 1/4	80	Flows.	
	625	5 3/16-4 1/4	150	Flows.	
Corpus Christi (10 miles west).	+675				
Corpus Christi					
Do	1,765		50		Mineral water at ab feet only.
Do	525		300		
Do	560		100		
—	402-1,240		5-400	Flow.	73 wells.
Palo Pinto County:					
Gordon	485		1	+ 23	Salt water.
Do	498	1	1	+ 23	Salt water and gas.
Parker County:					
Weatherford[2]	500			− 50	
Do	402		69	−250	Good water.
Do	440				
Do	488			−250	
Pecos County:					
Dryden	1,797	7 1/2-4	18	−600	
Do	590		Many.	−539	
Longfellow	683	8	20	No flow.	
Lozier	770	7 1/2	Few.	No flow.	
Pecos[3]	683		20		
Do	987		28		Do.
Do	1,797		16		Do.
Do	770		16		
Sanderson[4]	987	7 1/2	30	No flow.	
Sanderson	2,000				No water.
Polk County:					
Moscow (4 miles from)	400		Many.		
Valda	420	4	45	Flows.	
Valda (5 miles west of)[5]	543				
Valda	±1,000			Flows.	Abandoned.
Presidio County:					
Valentine	1,280				No water.
Red River County:					
Clarksville	1,060			Flows.	Brackish water; a doned.
Do	+1,100		Many.	+10 to +12	Salty water.
Do	+1,200			+ 23	Salty water; gas, als
Do	561	4	80	+ 23	Fine fresh water.
Do	600	8-6	Many.	− 50	Soft water.
Do	1,400		Many.	Flows.	
Do	1,800		Many.		Salty.
Reeves County:					
Pecos (4 miles west)	400			No flow.	
San Martina[6]	400		40		
Toyah	834	9-3	300	Flows.	Sulphur water.
Do	514	12	9	Flows.	
Refugio County:					
O'Connor Ranch	825-946		104-200	Flow.	3 wells.
Refugio[7]	853		104	Flows.	
Refugio	956		104	Flows.	
Do	1,000		347	Flows.	
Roberts County:					
Miami	− 500				Several wells in co
Robertson County:					
Bremond	1,500			No flow.	Some water.
Calvert[2]	460			30	
Do[8]	585-620	4	Many.	Flow.	Several wells.
Calvert (5 miles southwest).	510	1	Many.	Flow.	Several wells in vic
Do	900	1		+ 20	
Calvert (5 miles west)	400			− 20	
Do	800			100	
Franklin	1,200			No flow.	
Hearne	740			Flows.	Many wells in vici
Do	400-450	4		Flow.	Several wells.
Do					
Do	450-700	2	3-10	+10-+40	Do.
Hearne (8 miles south)	300-700		3	Flows.	

[1] U. S. Geol. Surv. Bull. No. 212, p. 18.
[2] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, p. 266.
[3] Record, etc., U. S. Geol. Surv., 18th Ann. Rept., 1896-97, part 2, p. 267.
[4] Ibid., p. 274.
[5] Record, U. S. Geol. Surv. Bull. No. 212, p. 54.
[6] Texas Univ. Mineral Survey Bull. No. 1 pp. 109-111.
[7] Record, 51st Cong., 1st sess., Senate Ex No. 222, pp. 266-267.
[8] Record, Texas Geol. Surv., 4th Ann. 1892, p. 109.

TEXAS—Continued.

›n.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
.y—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
niles north-	300–700	.....	8	Flows.	
.....	300–1,000	.....	2–12	.....	Several wells.
'ounty:					
ne (6 miles	415	6	Few.	+ 30	Good water.
ne (2 miles	700	.....	Many.	Flows.	Oil test well.
.nty:					
.....	983	.....	60	Flows.	
› miles east- ›f).	1,975	10–6	.....	Flows.	Artesian water at 1,030 and 1,215 feet; oil well in progress.
nty:					
.....	400	.....	Few.	.....	
.....	900	.....	.....	− 80	
.....	+ 500	4	3	+ 10	
.....	1,150	6	.....	.....	In progress, 1901.
.....	1,207	4¼–6	3	−100	
.....	+ 500	.....	Many.	.....	
.....	526–800	.....	15–250	Flow.	7 wells.
::					
e	1,400	.....	.....	.....	Failure.
.....	480	.....	.....	.....	Several wells.
.....	800	.....	.....	.....	Oil.
.....	1,480	.....	21	.....	Strong mineral water.
niles south).	602¼	.....	.....	Flows.	Soft water.
.....	406	.....	.....	No flow.	Do.
mile north).	486	.....	.....	− 20	Do.
ne-half mile	420	.....	Many.	Flowed once.	
.....	485	.....	.....	−130	Do.
.....	486	.....	3	No flow.	Do.
niles north-	446	.....	.....	−150	Do.
niles south-	430	.....	.....	No flow.	Do.
niles from)...	484	2	.....	−134	Do.
.....	442	.....	.....	−142	
› west).....	430	.....	5	− 60	
s northeast).	460	.....	Many.	− 90	Do.
.....	.....	.....	.....	.....	
.....	484	.....	.....	− 50	
.....	450	.....	.....	.....	
.....	465	.....	30	Flows.	
.....	950–1,400	10–4	140	Flow.	Several wells.
.....	4,000	.....	.....	.....	No flow below 1,200 feet; temp., 140° at 3,250 feet.
.....	760	.....	.....	Flows.	
(3 miles	1,200	.....	.....	.....	
h (10 miles	480	4¼	+208	.....	
(12 miles	534	.....	.....	−450	
(7 miles	+ 400	.....	.....	.....	
.....	423	.....	.....	No flow.	Soft water.
.....	509	.....	.....	− 25	Do.
ile south)...	430	.....	.....	−255	Do.
niles south-	480	.....	3	−258	
.....	400	.....	.....	.....	
.....	457	.....	50	− 50	
.....	430	.....	.....	.....	
e-half mile	1,200	.....	545	Flows.	Temp., 78°; soft water.
mile south).	500	.....	3¼	− 72	Soft water.
mile north-	516	.....	.....	− 10	Sulphur water.
e-half mile).	525	.....	156	Flows.	

sian waters of Texas west of 97th T. Hill: 52d Cong., 1st sess., Sen 41, part 3, pp. 105–106.

ng., 1st sess., Senate Ex. Doc. No.

[3] Record, Artesian waters of Texas west of 97th meridian, by R. T. Hill: 52d Cong., 1st sess., Senate Ex. Doc. No. 41, part 3, p. 104.

TEXAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Tarrant County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Randol (3 miles southwest).	420	.....	¼	Flows.	Soft water.
Randol (one-half mile north).	505	4	.....	Flows.	Do.
Timber	576	.....	2½	.....	Salty water.
Webb	800	.....	.....	−160	Poor water.
Taylor County:					
Abilene	2,500	.....	.....	.....	
Do	2,223	.....	.....	.....	
Merkel	+2,000	.....	.....	.....	
Tom Green County:					
San Angelo	960	.....	.....	.....	
Travis County:					
Austin (Fifth and Jacinto streets).[1]	2,020	.....	175	Flows.	
Austin (asylum)	1,280	.....	.....	.....	
Austin (poorhouse)	1,300	.....	5	No flow.	
Austin	471	.....	5	.....	
Do	1,450	.....	5	.....	
Austin (East Fifth street).	700	.....	14	Flows.	In progress 1897; water.
Austin (natatorium)[2]	2,025	10–8 and 7–6.	175	Flows.	Main flow at 1,8 temp., 100°.
Austin (asylum)[3]	1,975	.....	+104	+40	
Austin[3]	2,053	.....	.....	−5	
Do	1,280	.....	.....	.....	
Manor[4]	2,220	6	69	+30	Temp., 93°.
Roundrock	400	.....	1	No flow.	
Walters	700	.....	.....	.....	
Trinity County:					
Trinity	+900	.....	Few.	.....	Salty, sulphur wat
Tyler County:					
Kountze (15 miles west)	1,737	6–4	.....	.....	Dry hole.
——[5]	824	.....	.....	.....	2 miles from Neche between Rushai creeks.
Uvalde County:					
Sabinal	529	.....	.....	.....	
Uvalde	512	.....	Few.	−85	
Do	1,000	.....	.....	No flow.	
Valverde County:					
Comstock (20 miles from).[6]	569	.....	.....	.....	
Del Rio[7]	760	.....	.....	−60	Mineral waters.
Del Rio (30 miles north)	475	.....	.....	−300	
Del Rio (3 miles south)	460	.....	.....	Flows.	Sulphur water.
Van Zandt County					
Myrtle Springs	650	.....	.....	.....	Unsuccessful.
Wills Point	1,100	6	.....	To surface.	
Victoria County:					
Victoria	815–956	.....	70–200	Flow.	3 wells.
Do.[8]	953	.....	.....	.....	
Do	1,045	.....	80	Flows.	
Do	716	2	10	Flows.	
Victoria (17 miles south)	592	3	10	Flows.	
Victoria (20 miles southeast).	704	.....	30	Flows.	
Walker County:					
Huntsville	2,210	9–3	Many.	−100	
Ward County:					
Barstow	+500	.....	.....	No flow.	
Washington County:					
Brenham	600	.....	.....	.....	Failure.
Webb County:					
Encinal	900	.....	.....	−200	Good water.
Laredo	1,200	.....	.....	No flow.	
Wharton County:					
Pierce	1,509	2	.....	Flows.	
Pierce Station	850 or 900	.....	.....	.....	
Wilbarger County:					
Vernon[9]	(?)	.....	.....	.....	
Do	(?)	.....	.....	.....	

[1] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896-97, part 2, pp. 280-283.
[2] U. S. Geol. Surv., 18th Ann. Rept., 1896-97, part 2, pp. 280, 284.
[3] Ibid., pp. 280, 284.
[4] Record, ibid., pp. 285-286.
[5] Record, U. S. Geol. Surv. Bull. No. 212, p. 57.
[6] Record 51st Cong., 1st sess., Senate E No. 222, p. 284
[7] U. S. Geol. Surv., 18th Ann. Rept., 1896-2, pp. 265, 299.
[8] Record, U. S. Geol. Surv. Bull. No. 212.
[9] Analysis, Texas Geol. Surv., 4th Ann. 1892, p. 105.

TEXAS—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
lliamson County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Cornhill	404			−282	
Georgetown (2 miles east).	520		15		
Gravis (1½ miles south)	412		3	− 96	Sulphur water.
Roundrock	1,400			− 4	
Taylor	1,400		104	Flows.	
Do	2,800		27	Flow.	2 wells; poor water.
Do	1,500		15	+ 40	Several wells.
lson County:					
Gonzales	1,400		15	+ 60	Flows at 650, 950, 1,300, and 1,400 feet.
Do	625	10–8	30	Flows.	
Gonzales (1 mile north)	1,135		Many.	− 60	
Sutherland	1,500				For oil; unsuccessful.
e County:					
Newark	410	5	1	+ 14	Temp., 65°.
Park Springs	400	6	Many.	− 60	
Rhome	1,400				
od County:					
Mineola [1]	1,200	6–3		− 40	
alla County:					
Batesville	700			−300	

[1] Brown coal and lignite: Texas Geol. Surv. Rept. 1892, pp. 132–135.

INCIPAL PUBLICATIONS RELATING TO THE UNDERGROUND WATERS OF TEXAS.

leport of F. E. Roesler, division field agent for Texas, letter from the Secretary Agriculture transmitting a report on the preliminary investigations to determine proper location of artesian wells within the area of the ninety-seventh meridian l east of the foothills of the Rocky Mountains, Fifty-first Congress, first session: ate Ex. Doc. No. 222, pages 243–319, Washington, 1890.

leport of E. T. Dumble on the existence of artesian waters west of the ninety-enth meridian, etc., Fifty-first Congress, first session: Senate Ex. Doc. No. 222, es 99–102, Washington, 1890.

'reliminary reports on the artesian wells of the Gulf coastal slope, by J. A. gley: Texas Geological Survey Fourth Annual Report, 1892, pages 85–113, Austin, 3.

'n the occurrence of artesian and other underground waters in Texas, etc., west the ninety-seventh meridian, by R. T. Hill, report on irrigation, Fifty-second ıgress, first session: Senate Ex. Doc. No. 41, part 3 (Final Geological Reports), es 41–166, plates, Washington, 1893.

ieology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San tonio, Tex., with reference to the occurrence of underground waters, by Robert T. l and T. Wayland Vaughan: United States Geological Survey, Eighteenth Annual ›ort, 1896–1897, part 2, pages 193–321 and plates, Washington, 1898.

ieography and geology of the Black and Grand prairies, Texas, with detailed criptions of the Cretaceous formations and special reference to artesian waters, by T. Hill: United States Geological Survey, Twenty-first Annual Report, 1899–1900, t 7, pages 1–649, Washington, 1901.

'il Fields of Texas-Louisiana Gulf Coastal Plain, by C. W. Hayes and William nnedy, United States Geological Survey Bulletin No. 212, Washington, 1903.

ieology and water resources of northern Louisiana and southern Arkansas, by C. Veatch: Prof. Paper U. S. Geol. Survey No. 46. (In preparation.)

UTAH.

Location.	Depths.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Beaver County:					
Milford	400–470	2–4½	7–20	+1½–2	Good soft water; ature of flow in well is 80°.
Boxelder County:					
Ogden (50 miles west)	780	.....	.....	No flow.	Salt water.
Utah Hot Springs	600	.....	.....	.....	Test well for ga heavy pressure below 500 feet.
Cache County:					
Benson	460	2	50	+18	Good water; lithia.
Bensonward	480, 510	.....	.....	.....	
Cache Junction	430	3	.....	−8	Good sulphur wa
King	430	1½	5	.....	Good water, so and gas; temp.
Logan	400–480	2	8–20	+3–12	Good soft water.
Logan (9 miles northwest).	480	2	50	+4	Do.
Logan (SW. ¼ sec. 1)	496	.....	.....	.....	
Smithfield	410	.....	3	.....	
Davis County:					
Bountiful	400	.....	4–60	.....	
Bountiful (2 miles northwest).	580	.....	.....	.....	No water.
Layton	500	4½–1½	Few.	.....	
East Bountiful	30–500	2	10–120	+10–30	Many wells.
Farmington	±2,000	.....	.....	.....	For oil; unsucces
Hooper (near)	1,088	2	.....	27	Good hard, clear
Kaysville	500–574	2–3	10–30	+2–6	Good soft water; ature of flow in well is 62°.
Syracuse	400–1,000	.....	.....	Flow.	
Woods Cross	500	2	30	Flows.	Good water, trac and sulphur; ture of flow, 54°
Emery County:					
Desert	990	6	.....	Flows.	
Green River	1,400	11–4½	.....	−15	Mineral water; n
Green River (18 miles west).	1,335	14–6½	11	+74	Considerable su the water, also iron and magn
Green River (17 miles northwest).	1,325	10–6½	.....	Flows.	Alkalinewater; t
Iron County:					
Lund	585½	12–6	50	−6	Water contains amount of st and dissolved s
Paragonah	412	2	.....	.....	Cool water.
Parowan (4 miles north).	500	2	.....	+10	Very hard water.
Juab County:					
Fishsprings	400	1½	10	−12	Hard, salty water
Kane County:					
Sulphur Springs	650	.....	.....	No flow.	
Millard County.					
Clear Lake	400–1,325	2½–4	.....	−1–5	Good water
Fillmore	600	.....	.....	.....	In progress, test water, prospect ing oil.
Piute County:					
Circleville	450	.....	.....	.....	
Salt Lake County:					
Brighton	409, 411	.....	.....	.....	
Draper	500	.....	.....	No flow	
Eldorado	412	2	.....	+12	Good soft sulphu temp., 70°.
Do	1,365	.....	25	.....	
Salt Lake City (Rio Grande and Western R. R.).	1,073	.....	120	Flows.	
Salt Lake City (Utah Light and Power Co.).	920	4	120	+12	
Salt Lake City (Inland Crystal Salt Co.).	800	6–4	110	.....	Some salt and temp., 60°.
Salt Lake City	950	6	120	+50	Temperature of f
Do	600	8	.....	Flows.	Good soft water 55°.
Do	550	8	500	.....	
Do	1,105	8	350	.....	
Salt Lake City (12 miles north).	500–750	.....	.....	.....	Several wells.

UTAH—Continued.

tion.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
.....	1,004	.....	.....	.....	
.....	432	2	5	+20	Slight amount of sulphur and iron in water.
.....	400, 1,000	.....	.....	.....	
.....	2,700	.....	+8	.....	Water soft, slightly alkaline.
.....	500	2-¼	.....	.....	Abundant supply of water.
.....	979	.....	.....	.....	Abandoned.
.....	900	8	.....	.....	Surface water only.
Fork	500	.....	.....	.....	Many wells of same depth.
.....	543	3	12	−4¼	Good water.
.....	560	2	20	Flows.	Soft water with slight trace of sulphur; temp., 72°.
.....	400	.....	.....	Flows.	
ork (4 miles -office).	404	2	15	+¼	Good soft water.
rk.....	404	.....	.....	Flows.	
.....	420	2	60	.....	
.....	400	2	5	.....	
.....	400	2	70	.....	
.....	410	2	40	.....	
.....	400-1,000	2	.....	.....	
.....	450	.....	.....	Flows.	

VERMONT.

unty:					
n	1,255	8-6	.....	.....	
unty:					
.....	410	8	.....	− 15	
.....	430	8	60	− 15	
.....	490	6	.....	.....	
Allen	496	8	110	−100	
.....	1,400	6	.....	.....	
.....	495	8	21	Flows.	

VIRGINIA.

unty:					
(brewery) ..	430	8	90	.....	
(ice works).	401	8	20	.....	
nty:					
.....	1,138	.....	400	.....	
ty:					
k	460	5	10	− 50	
asylum).....	696	5	60	− 60	
mile east)....	460	5	9	− 30	
ty:					
Springs.....	500	6	75	.....	
County:					
each.....	+100	.....	.....	.....	
e[1]	907	.....	.....	.....	Drilled in 1864: saline water flowed at 591 feet.
.....	945	.....	50	+ 17	Saline water.
.....	2,254	.....	.....	− 20	Salty water at 1,320 and 2,131 feet; horizons of water not tested at 630, 985, 1,520, 1,630, 1,915, and 1,945 feet.
Point[4]	1,172	.....	Not any.	.....	
y:					
.....	620	1	2	Flows.	
t[5]	560	.....	Many.	No flow.	Water at 270 feet; rock below.
nty:					
.....	538	1	Several.	Flows.	
.....	600	.....	Not any.	.....	
.....	716	6	50	+ 23	

ology of the Virginias, by W. B. York, 1884, pp. 731-736; Am. Inst. Trans., vol. 24, pp. 380-384; U. S. ll. No. 138, p. 167.
., N. J. Geol. Surv., Rept., 1898, pp. ieol. Survey Folio No. 80.

[3] Record, U. S. Geol. Surv. Folio No. 80.
[4] Record, Am. Inst. Mining Eng. Trans., vol. 24, pp. 384-386.
[5] Record, U. S. Geol. Surv. Bull. No. 138, p. 178.
[6] N. J. Geol. Surv., Rept., 1899, pp. 86-87.

VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Greene County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Stanardsville	1,150				For oil; no success.
Henrico County:					
Cotman	730		40	No flow.	In granite.
Richmond (paper mill)	400		Several.		
Richmond (Sherwood Park).	900		Not any.		
Richmond (Ginter Farm).	400		Many.		
Richmond	445				Small supply of w 102 feet.
James City County:					
Williamsburg	876		Not any.		
Lancaster County:					
Lancaster	+400			No flow.	
Windmill Point	450				Abandoned.
Norfolk County:					
Lambert Point[1]	616	6	65	+ 23	Temperature about
Norfolk (Money Point)	562		Many.	Flows.	Ferruginous water.
Norfolk (waterworks).[2]	1,760	12–4½	150	Flows.	Saline waters at s horizons.
Northumberland County:					
Dymer Creek[3]	507				
Fairport[4]	662	8–6	75	Flows.	
Reedville	680	8–6	85	+ 3	Temp., 78°.
Nottoway County:					
Crewe	500		Few.	Flow.	
Allisonia	400–1,200				Several wells.
Delton	+400		Not any.		Abandoned.
Dublin	475	6	25	−80	
Pulaski	400–600	6	100	−10	Several wells.
Do	1,200				
Princess Anne County:					
Virginia Beach[5]	600				Only small amou water.
Rockingham County:					
Harrisonburg	420	8		−10	
Roanoke County:					
Roanoke	1,200	6		− 4	Not in use.
Warwick County:					
Newport News[5]	600		Few.	No flow.	
Wise County:					
Stonega	503	8	55	−16	
Toms Creek		6	100	No flow.	
Wythe County:					
Foster Falls	808		100	− 2	
Miscellaneous:					
Oak Springs	400	1	Several.	Flows.	

[1] Record, U. S. Geol. Surv. Folio No. 80; No. 138, p. 172; N. J. Geol. Surv. Rept., 1899, pp. 87–92.
[2] Record, etc., N. J. Geol. Surv. Rept., 1899, pp. 92–102; U. S. Geol. Surv. Folio No. 80.
[3] Record, U. S. Geol. Surv. Bull. No. 138.
[4] N. J. Geol. Surv. Rept., 1898, pp. 121–122
[5] U. S. Geol. Surv. Folio No. 80, p. 4.

PRINCIPAL PUBLICATION RELATING TO DEEP WELLS I VIRGINIA.

Artesian well prospects in the Atlantic Coastal Plain region, by N. H. D United States Geological Survey Bulletin No. 138, 232 pages, 19 plates, Was ton, 1896.

United States Geological Survey Folio No. 80, by N. H. Darton.

WASHINGTON.

Location.	Depths.	Diameter.	Yield per minute.	Height of water.	Remarks.
Adams County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Cunningham	426	6		+ 356	Soft water; suppl creasing.
Eureka Flat (southeast of Snake River).	200–900				Several wells.
Franklin County:					
Connell	676	5		−640	Farm supply; soft temperature of w mouth, 51°.

WASHINGTON—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
klin County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
onnell (6 miles southeast).	674				Braden well.
onnell (3 miles southeast).	420(?)				Brummond well.
onnell (west of)					Many wells.
'asco[1]	527 404	6	Many.	Flows.	
Do	400		Few.		
:ye Grass (near)	575				Good supply of water.
ulphur (6 miles south).	975		5–6		Mineral (?) water at 600 feet, which rises 100 to 125 feet; pump, 2½ inch; black basalt most of way.
ulphur (5 miles south).	575				Not very good supply of water; in basalt; Dunigan well.
ulphur Lake (6 miles north).	676				Little water.
rson County:					
unction City	800	1½	½	Flows.	Abandoned.
'ort Discovery	800				Do.
'ort Townsend	1,060				For coal; unsuccessful.
'ort Townsend (3 miles from).	1,500				Do.
'ort Townsend (9 miles from).	1,100				For coal; unsuccessful.
'ort Townsend (15 miles from).	700				Do.
'ort Townsend (18 miles from).	900				Do.
'ort Townsend (near)	1,300				Well at Fort Flagler.
ıp County:					
'ort Blakely	410	4½	500	− 6	
itas County:					
Ellensburg (2 miles northwest).	700			−40	Unsuccessful.
Roslyn	700		Many.	Flows.	
Port Discovery (4 miles northeast).	1,230				
ens County:					
Colville	700	10–6			Water irony.
lawalla County:					
Walla Walla	564	6	130		Temp., 67°; irrigation.
ima County:					
North Yakima	625	5½–3	+1	Flows.	Temp., 74°; flow decreasing; sulphurous.
Do	826	4–2½		+40	Temp., 78°; soft water.
Do	626			Flows.	Soft water; used for irrigation; temp., 74°.
Do	828	6		+ 4	Do.
Do	570	6½–2½		+20	Soft water; used for irrigation; temp., 60°.
Do	1,020	4½		+80	Soft water; used for irrigation; temp., 75°.
Do	1,200	3½		Flows.	Soft water; used for irrigation; temp., 81°; sulphurous.
Do.[2]	404	6	Many.	Flows.	
Do	534–835	8, 6 and 3	Many.	Flow.	Several wells.
Do	650		Many.	Flows.	Temp., 71°.
Do	1,050	5–3½		+110	
Do	940	6–4		Flows.	
Prosser	500		Many?	No flow.	

WEST VIRGINIA.

bour County:					
Elk Creek (below Philippi).[3]	1,915				For oil or gas.
Philippi (4 miles west)[4].	2,594				Do.
——	734				For oil.
—— 4 miles northwest.[5]	541				Do.
—— near[6]	2,725				Show of oil at 1,376 feet.

:ecord, U. S. Geol. Surv. Bull. No. 108, p. 39.
bid., pp. 56–58.
:ecord, W. Va. Geol. Surv. Rept., vol. 1 (a), p. 348.
[4] Ibid., pp. 346–348.
[5] Ibid., vol. 2, pp. 357–358.
[6] Ibid., vol. 1 (a), 1904, pp. 344–346.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Berkeley County:					
Martinsburg	485				Abandoned.
Do	450				
Shanghai	714	7	Few.		Sulphur water at 18 abandoned.
Boone County:					
Racine (township)[1]	1,335				
Racine (near)[2]	1,401				Show of oil.
Boyd County:					
Catlett Creek (township).	2,025				
Central City (vicinity)	1,675–1,775				2 oil wells.
Braxton County:					
Bulltown	1,000				Salt well.
Burnsville	2,750				Small flow of oil.
Burnsville (opposite B. & O. station).[3]	2,282				Oil and gas.
Burnsville (2 miles northeast).[4]	2,800 2,920				Oil and gas; 2 wells
Fallsmill	1,000				Salt well.
Rosedale (and vicinity)[5]	1,610–3,275				Several wells; oil or
Sutton (1½ miles below)[6].	2,725				Oil well.
Brooke County:					
Bethany (2½ miles northwest).[7]	2,273				Dry.
Bethany[7]	1,577				"Dry hole."
Bethany (2 miles below)[8]	1,509				"Oil and gas in t Berea," about a 3 rel well.
Bethany[8]	1,546				5-barrel well.
Cross Creek district[9]	765				For oil; unproductiv
Wellsburg[10]	1,217				Numerous deep gas now run out.
Do.[11]	1,310				Gas well.
Township unknown	765				Dry.
Cabell County:					
Central City (one-fourth mile back of C. and O. depot).[12]	2,770				For oil or gas.
Central City	2,900	8¼–6¼	Many.	Flows.	Some oil.
Do.[13]	2,770				Small flow of gas.
Central City Township	2,970				
Greenbottom Township[14]	2,550				
Huntington Township[14].	1,977				
Huntington	2,975	8¼–6¼			Oil prospect; unsucce much water at bot
Do	1,200	8–6			
Milton (and vicinity)[15]	935–2,776				Several oil and gas w
Toms Creek Township	1,755				
Calhoun County:					
Ayers Post-Office (1 mile west).[16]	2,150–2,289				Oil wells.
Bear Run[16]	1,736				"Dry hole."
Cairo (15 miles south)[17]	1,837				Oil well.
Grantsville (3 miles west).[18]	2,540				For oil or gas.
Rhoda (vicinity)[19]	2,143–2,422				Several oil wells.
Richardson (vicinity)[20]	2,212–2,575				Do.
Sherman district[21]	881				Oil well.
Do.[22]	2,901				
Spring Fork of Yellow Creek.[18]	2,155				For oil or gas.
On Yellow Creek (Jackson farm).[23]	2,442				
Clay County:					
Big Otter	1,100				

[1] U. S. Geol. Surv. Folio No. 72, p. 4.
[2] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 499–500.
[3] Ibid., p. 391.
[4] Ibid., pp. 392–393.
[5] Ibid., pp. 388–390.
[6] Ibid., vol. 1, 1899, pp. 269–270.
[7] Ibid., vol. 1(a), 1904, p. 233.
[8] Ibid., p. 232.
[9] Record, Pa. 2d Geol. Surv. Rept., vol. 1[5], pp. 327–328.
[10] Record, Ohio Geol. Surv. Rept., 1888, vol. 6, pp. 337–339.
[11] Record, Pa. 2d Geol. Surv. Rept., 1886, part 2, pp. 783–784; W. Va. Geol. Surv. Rept., vol. 1, p. 367.
[12] Record, W. Va. Geol. Surv. Rept., vol. 1904, pp. 495–496; U. S. Geol. Surv. Folio No. 6
[13] Ibid., vol. 1, pp. 275–276.
[14] U. S. Geol. Surv. Folio No. 69, p. 3.
[15] Record, W. Va. Geol. Surv. Rept., vol 1904, pp. 484–495.
[16] Ibid., p. 395.
[17] Ibid., pp. 394–395.
[18] Ibid., p. 397.
[19] Ibid., pp. 398–401.
[20] Ibid., pp. 401–402.
[21] Ibid., vol. 2, p. 396.
[22] Ibid., vol. 1(a), 1904, pp. 396–397.
[23] Ibid., vol. 2, pp. 395–396.

WEST VIRGINIA—Continued.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
–Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
d Clendenin ay between).[1]	2,614				Produced 2 barrels of oil a day; well abandoned
n County line[2].	2,422	8¼–6¼			For oil or gas.
ounty:					
st-Office (1¼ and southwest and	2,795				Gas well.
	2,843				Gas, 1,869 feet; oil, 1,905 feet; gas, 2,835 feet.
Creek (2 miles st from mouth)[4]	2,520				Oil well.
near)[5]	2,760				Gas and oil.
Point (1 mile	1,950				Gas, 1,890 to 1,895 feet; gas and oil, 1,902 feet.
int (near)[7]	1,910–2,880				Several oil wells.
	460	5		−20	Sulphur water.
tation (three- to 2 miles	1,879–3,085				7 wells; for oil or gas.
rict[9]	2,595–2,782				5 wells; for oil or gas.
e-Lewis County	2,186				2 wells; for oil or gas.
ar).[10]	2,207				
rict[11]	2,257–3,314				13 wells; for oil or gas.
r district[12]	2,750–3,193				8 wells; for oil or gas.
d Post-Office southeast).[13]	2,081				
Post-Office (2 uthwest).[14]	2,500				"Good Injun gas well."
) (vicinity)[15]	2,115				For oil or gas.
Post-Office (1¼	2,587				"30-barrel well."
le northwest).[16]	2,564				"10 to 20 barrel well."
n station	2,701				For oil or gas.
district[18]	2,158–3,206				9 wells; for oil or gas.
	2,791–3,131				4 gas wells.
	2,773				Gas at 2,771, 2,778, and 2,800 feet, so strong that drilling had to be suspended.
near)[20]	2,930				For oil or gas.
	2,670				Gas well.
ille (1 mile est).[21]	2,723				For oil or gas.
n district[22]	2,047–2,906				6 wells; for oil or gas.
½ miles north-	2,655				For oil or gas.
miles above)[24]	2,484				Oil well.
2½ miles north-	2,770				For oil or gas.
near)[26]	2,800				Large gas well.
	2,800–3,295				6 wells; for oil or gas.
	2,207				For oil, unsuccessful on account of water.
on (3 and 3¼	2,493				Practically dry hole.
uthwest).[29]	+1,745				"Big gas, 1,750 feet."
iles north- [30]	2,479				
ty:					
l	541				
[33]	+813				
	2,895				For oil or gas.
y:					
Fork of Sand Creek (near ounty line).[34]	2,825				

[1] . Va. Geol. Surv. Rept., vol. 1(a), 75.
[2] 173–474.
[3] 287–288.
[4] ol. Surv. Rept., vol. 1, pp. 332–334.
[5] nd., vol. 1(a), 1904, pp. 282–283.
[6] 281–282.
[7] 1, pp. 328–332.
[8] 1(a), 1904, pp. 302–304.
[9] 297–300.
[10] 98.
[11] 288–292.
[12] 292–294.
[13] 3.
[14] 0.
[15] 1, p. 335.
[16] 1(a), 1904, p. 297.
[17] 1, pp. 325–326.
[18] Ibid., vol. 1(a), 1904, pp. 285–287.
[19] Ibid., p. 282.
[20] Ibid., vol. 1, pp. 323–324.
[21] Ibid., vol. 1(a), 1904, p. 301.
[22] Ibid., pp. 295–297.
[23] Ibid., p. 304.
[24] Ibid., vol. 1, 322–323.
[25] Ibid., vol. 1(a), 1904, p. 298.
[26] Ibid., vol. 1, pp. 326–327.
[27] Ibid., vol. 1(a), 1904, pp. 282–284.
[28] W. Va. Geol. Surv. Rept, vol. 1, pp. 258–259.
[29] Record, ibid., vol. 1(a), 1904, pp. 300–301.
[30] Ibid., p. 301.
[31] Partial record, ibid., vol. 2, pp. 661–662.
[32] Ibid., p. 622.
[33] Record, ibid., vol. 1(a), 1904, pp. 502–503.
[34] Ibid., pp. 380–381.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Gilmer County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Glenville district [1]	2,678–3,218				Several wells for oi
Do. [2]	2,908				
Glenville [3]	2,412	7¼			Oil and gas well.
Do	800	2¼			For oil or gas; aban
Joes crossing [2]	2,830				
Stouts Mill [4]	694				
Stouts Mill (2 miles northeast). [5]	2,898				Oil.
Stouts Mill (near) [6]	2,672				
Stumptown (and near). [7]	1,215–2,668				Several oil and ga
Tanner (1 mile west). [8]	2,710				For oil or gas.
Troy district [9]	2,276–3,204				Several oil and ga
Greenbrier County:					
Ronceverte	800				For oil; abandone
Hancock County:					
Chester (4½ to 7 miles southeast). [10]	1,090–2,266				8 oil and gas wells.
Fairview (10 miles northeast of Manington). [11]	1,999				Heavy gas at 1,99 show of oil.
Grant district [12]	1,470				For oil; unproducti
Grant district	960, 980				2 wells.
Holidays Cove (near) [13]	1,296				Dry hole.
King Creek (along, in Turkey Foot field). [14]	1,201–1,296				7 wells.
New Cumberland	+600				Gas well.
New Cumberland (2 miles east). [15]	1,198				Oil well.
Poe district [16]	1,700				For oil. unproducti
Harrison County:					
Bridgeport	±2,500				2 oil wells.
Brown (1¼ miles northeast). [17]	3,685				
Browns Mills (near) [18]	1,867				For oil; unproducti
Cherry Camp (near) [19]	3,146				"Dry hole."
Cherry Camp (vicinity) [20]	2,556–2,839				Several oil and gas
Clarksburg	1,700		Many	Flows.	Some gas.
(5 miles east)	2,000				
(4 miles south)	750		Many.	Flows.	Salt water.
(2 miles north). [21]	2,523	10–6¼			Oil and gas.
	2,517				"Medium gas well.
Cunningham Run (head). [22]	2,485				Gas well.
Gypsy (1 mile east) [23]	2,697				"Three million-fo well in Big Injun:
Jarvisville	2,500–2,800				Numerous oil wells
Lumberport (2 miles east). [24]	2,347				Gas well.
Marshville (2 miles northwest). [25]	3,038				Oil. "40-barrel wel
Olive (2 miles west) [26]	3,160				Oil; "275-barrel we
Peoria	2,300				For oil or gas.
West Milford (near) [27]	2,225				Little gas; show of
West Milford [27]	2,460				Do
Salem	2,100–2,800				Oil wells.
Sardis (vicinity) [28]	3,081				For oil; abandone
Sardis district [29]	2,742–3,299				For oil; 14 wells.
Nos. 1 and 2 [30]	2,930, 3,127				J. J. Ashcraft wells
—— [24]	2,828–2,725				2 oil wells.
Simpson Creek (3 miles from mouth). [31]	2,502				"Dry hole."

[1] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 376–377.
[2] Ibid., p. 381.
[3] Ibid., vol. 1, pp. 259–260.
[4] Ibid., vol. 2, p. 243.
[5] Ibid., vol. 1(a), 1904, pp 377–378
[6] Ibid., pp. 378–380.
[7] Ibid., pp. 383–386.
[8] Ibid., pp. 386–388.
[9] Ibid., pp. 382–383.
[10] Ibid., pp. 236–237.
[11] Geol. Soc. Am. Bull., vol. 3, pp. 191–192, 1892.
[12] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 328.
[13] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, p. 237.
[14] Ibid., 234–235.
[15] Ibid., vol. 1, p. 369.
[16] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 327.
[17] Record, W. Va. Geol Surv. Rept., vol 1904, p. 311.
[18] W. Va Geol Surv Rept, vol. 1, 18 249–250.
[19] Ibid., vol. 1 (a), 1904, pp. 317–318.
[20] Ibid., vol. 1, 1899, pp. 252–255.
[21] Ibid., vol. 1 (a), 1904, pp. 328–330.
[22] Ibid., p. 328.
[23] Ibid., pp. 330–331.
[24] Ibid., p. 327.
[25] Ibid., p. 315.
[26] Ibid., p. 310.
[27] Ibid., pp. 334–335.
[28] Ibid., vol. 1, 1899, pp. 248–249.
[29] Ibid., vol 1 (a), 1904, pp. 305–311.
[30] Ibid., p. 309; authority, South Penn. O
[31] Ibid., p. 330.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
son County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
en Mile district[1]	2,750				For oil or gas; unproductive.
Vicinity of Sedalia and Salem.[2]	2,868–3,609				16 wells, for oil or gas.
——[3]	2,578–3,483				24 wells; covering the region where the Fifth Sand is productive of oil or gas.
nion district[4]	2,160–3,018				16 gas and oil wells; the 2,160-foot well is the largest gas well in the State at present.
on County:					
ottageville[5]	2,175				For oil or gas.
entuck Post-Office (southeast of).[6]	1,670	10–4¼			"Big gas pressure at 1,420 feet; show of oil at 1,430."
enna Post-Office[7]	2,475				"Dry hole."
avenswood (near)[8]	2,232				For oil or gas.
andyville (near)[9]	1,787				Gas, water, and little oil at 1,787 feet.
son County:					
arpers Ferry	412		Few.	No flow.	
awha County:					
abin Creek Township	2,000				
harleston (waterworks).[10]	1,840				For oil or gas; unproductive.
8 miles above[11]	2,450				Moderate flow of gas.
9 miles above[12]	2,542				Small flow of gas.
13 miles southwest[13]	2,000				For oil or gas; unproductive.
5 miles below[14]	1,425				
——[15]	2,608				For oil or gas.
——[16]	1,840				Do.
ool Spring Fork of Burning Spring Branch.[17]	2,542				
ork of Little Sandy (on Simmons farm).	1,700	13–6¼			Gas well, water at 60 and 155 feet, hole filled with salt water, 940–990 feet; gas at 938 feet.
anawha (and vicinity).[18]	1,000–2,450				Numerous salt and gas wells.
anawha River at head of Witchers Creek[19]	1,208				
ens Creek Township[17]	1,222				
ewis Creek (1¼ miles from Kanawha River)[19]	1,200				
aiden Township	2,450				
aiden	1,800				Gas well.
impsons Creek[19]	1,222–1,280				
inifrede[19]	2,000				
s County:					
amden (near)[20]	2,455				Do.
ourt-House district[21]	2,530–3,127				15 oil and gas wells.
reemans Creek district[22]	1,675–3,088				33 oil and gas wells
ightburn (vicinity)	2,700				For oil or gas; abandoned.
adis (near)[23]	2,703				Oil well.
Weston	2,700				For oil; unsuccessful.
——	1,150				Small flow of oil.
2 miles below[24]	2,142				Gas well.
10 miles southeast[25]	2,401				Oil well.
Hospital for the Insane.[26]	2,112				Gas well.

W. Va. Geol. Surv. Repts., vol. 1, 1899, p 251
Ibid., vol. 1 (a), 1904, pp. 311–316.
Ibid., pp. 319–326.
Ibid., pp. 331–337.
Record, ibid., pp. 476–477.
Ibid., p. 477.
Ibid., pp. 477–478.
W. Va. Geol. Surv. Rept., vol. 1, pp. 283–284.
Record, ibid. vol. 1 (a), 1904, p. 476
Record, Pa. 2d Geol. Surv. Rept., vol. I[5], pp. 332.
Ibid., p. 330.
Record, W. Va. Geol. Surv. Rept, vol. 1, pp. 272.
Record, Pa. 2d Geol. Surv. Rept, Vol. I[5], pp. 333.
Record, W. Va. Geol. Surv. Rept, vol. 2, p. 400.
Ibid., vol. 1 (a), 1904, pp. 500–501.
Ibid., p. 501.
U. S. Geol. Surv. Folio No. 72, p. 3.
Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], pp. 329–333, W. Va. Board of Centennial Managers, Resources Report by Maury and Fontaine, pp. 287–290
U. S. Geol. Surv. Folio No. 72, p. 4.
Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 357–358.
Ibid., pp. 369–373
Ibid., pp. 360–368.
W. Va. Geol Surv. Rept, vol. 1, pp. 257–258.
Record, ibid, vol. 1 (a), 1904, pp. 354–355.
Ibid., vol. 1, pp. 255–256.
Ibid., vol. 1 (a), 1904, pp. 355–356.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Lewis County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Weston (4 miles from)[1]	2,202				Oil and gas.
10 miles southwest[2]	2,645				Oil well.
16 miles south[3]	2,986–2,517				2 wells for oil or gas.
Lincoln County:					
Big Hart Creek[4]	3,261				
Hart (near)[5]	3,260				For oil or gas.
Logan County:					
(Township unknown)	1,710				
McDowell County:					
Welch[6]	+605				
Marion County:					
Barrackville (3 miles northwest).[7]	2,873				
Brink Post-Office (1 mile east).[8]	3,345 2,649				
2 miles from[9]	3,088				
1 mile east[9]	3,139				
Campbells Run[10]	3,218 3,340 3,064 3,202				For oil or gas; 4 well
Dunkard Mill Run (near headwaters).[11]	2,717 2,750				2 wells.
Fairview (southwest)[12]	1,889				Oil well.
2 miles northeast[13]	1,997				For oil; unproductiv
2 miles south.[14]	1,970	$5\frac{3}{16}$			Gas well.
Fairview (near)[14]	3,028 3,333				Some gas at 3,293 fe barrels of oil daily 3,315 feet.
	3,015 3,135				Produced 200 barrels daily, in July, 1903 still yields 68 b daily.
Farmington station (2 miles east).[15]	2,811				For oil or gas; aband
Flat Run[16]	3,064–3,374				6 wells; for oil or ga
Glovers Gap (1 mile east).[17]	2,284 2,404 2,263				
Glovers Gap (near)[18]	2,967 3,090 3,299				
Joetown (1 mile west)[19]	3,014				For oil or gas.
Joetown (near)[20]	2,495 2,759 2,889				Do.
Manington Township	1,945				
Manington (near)[21]	1,928				Do.
1 mile above[22]	3,144				Do.
3 miles southwest[23]	3,042				Do.
3 miles north[24]	2,895				Oil well.
6 miles northwest[25]	3,010				Do.
3 to 4 miles east[26]	3,025				Gas at 2,420 feet belo Pittsburg coal.
Near[27]	1,877 3,000				For oil or gas.
——[27]	2,631				Do.
2 miles west[27]	1,965 1,970	$8\frac{1}{4}$–$5\frac{3}{16}$ $8\frac{1}{4}$–$5\frac{3}{16}$			Do.
Near[27]	2,400 2,630	10 –4 $8\frac{1}{4}$–$5\frac{3}{16}$			Do.
3 miles southwest[27]	2,903				Gas.
Near[27]	2,255–3,020				11 wells; oil and gas

[1] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), pp. 356–357.
[2] Ibid., p. 369.
[3] Ibid., p. 374.
[4] U. S. Geol. Surv. Folio No. 69, p. 4.
[5] Record, W. Va. Geol. Surv. Rept. vol. 1, pp. 280–281.
[6] Ibid., vol. 2, pp. 694.
[7] Ibid., vol. 1 (a), 1904, pp. 152–154.
[8] Ibid., p. 165.
[9] Ibid., pp. 173–174.
[10] Ibid., pp. 167–168.
[11] Ibid., pp. 154–155.
[12] W. Va. Geol. Surv. Rept., vol. 1, pp. 239–241.
[14] Ibid., pp. 238–239.
[14] Record, ibid., vol. 1 (a), 1904, pp. 156–157.
[15] Record, Pa. 2d Geol. Surv. Ann. Rept part 2, pp. 782–783.
[16] Record, W. Va. Geol. Surv. Rept., vol 1904, pp. 169–173.
[17] Ibid., p. 164.
[18] Ibid., pp. 165–167.
[19] Ibid., vol. 1, pp. 345–347.
[20] Ibid., vol. 1 (a), 1904, pp. 174–176.
[21] Ibid., vol. 1, pp. 241–242.
[22] Ibid., pp. 242–243.
[23] Ibid., pp. 243–244.
[24] Ibid., pp. 244–246, vol. 2, pp. 129–130.
[25] Ibid., pp. 246–247.
[26] Ibid., vol. 1 (a), 1904, pp. 155–156.
[27] Ibid., pp. 158–164.

WEST VIRGINIA—Continued.

ation.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
ty—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
ton district	3,218	.....	.....	.....	Oil at 3,113 feet.
of Campbells					
ar)[2]	2,992	.....	.....	.....	For oil or gas.
unknown	2,811	.....	.....	.....	Dry.
(near)[3]	2,539	.....	.....	.....	For oil or gas.
nty:					
(3 miles north-	2,970	.....	.....	.....	
es southwest[5]	2,869	.....	.....	.....	Good oil well.
4 miles south-	3,085	.....	.....	.....	Oil at 3,075 feet; gas at 3,085 feet.
it.[5]					
2 miles north)[6]	2,798	.....	.....	.....	
(one-half mile	3,225	.....	.....	.....	Oil and gas.
(near)[8]	3,249	.....	.....	.....	For oil or gas.
es southwest[9]	2,810	.....	.....	.....	
west[9]	2,913¼	.....	.....	.....	
Post-Office (3¼	904	.....	.....	.....	"Gas on top; best well in this field."
outheast).[10]					
.....	970	.....	.....	.....	"Struck oil at about 945 feet, and shot with 60 quarts below this depth which shut off the oil and opened up the gas."
.....	937	.....	.....	.....	"Use gas for drilling purposes, piped to Elmgrove, probably 2,000,000 feet, with rock pressure of 260 pounds."
es southeast[11]	1,050	.....	.....	.....	
district[12]	2,616	.....	.....	.....	
near)[7]	3,249	.....	.....	.....	
ownship[13]	2,934	.....	.....	.....	For oil or gas; unproductive.
district[14]	2,656–3,108	.....	.....	.....	
ille (5 miles[15]	1,935	.....	.....	.....	For oil or gas.
le (near)[16]	2,603	.....	.....	.....	
.....	1,055	.....	.....	.....	Gas well.
strict[18]	2,477–2,949	.....	.....	.....	For oil or gas.
ille (east edge)[19]	2,579	.....	.....	.....	Do.
	1,465	.....	.....	.....	
0	1,470	.....	.....	.....	For oil or gas.
ity	1,400–1,413	.....	.....	.....	Several oil wells.
es northeast[21]	578	.....	.....	.....	Numerous oil wells.
es east[22]	2,707	.....	.....	.....	Dry.
1mile west)[12]	2,999	.....	.....	.....	Gas, 2,980 to 2,990 feet.
Rock station[23]	2,920	.....	.....	.....	
Post-Office[5]	2,945	.....	.....	.....	
es northeast[23]	2,974	.....	.....	.....	2 wells.
	2,747	.....	.....	.....	
alf mile north-	2,875	.....	.....	.....	
it.[24]					
District[25]	2,756	.....	.....	.....	
y:					
(mile1south).[26]	2,400	8¼–4¾	.....	.....	For oil or gas.
.....	1,800	.....	.....	—100	
ear)[27]	2,139	.....	.....	.....	Do.
asant (6 miles[28]	2,942	.....	.....	.....	Do.
es from[29]	1,677	13–4¾	.....	.....	Do.

W. Va. Geol. Surv. Rept., vol. 1 (a),

eol. Surv. Rept., vol. 1, 348.
bid., vol. 1 (a), 1904, pp. 151–152.
215–216.
218.
219.
214.
ol. Surv. Rept., vol. 1, p. 350.
bid., vol. 1(a), 1104, p. 215.

26.
22.
a. 2d Geol. Surv. Rept., vol. I[5], pp.

V. Va. Geol. Surv. Rept., vol. 1(a), pp.

[15] W. Va. Geol. Surv. Rept., vol. 1, pp. 351–352.
[16] Record, ibid., vol. 1(a), 1904, pp. 227–229.
[17] Ibid., p. 230.
[18] Ibid., pp. 220–222.
[19] Ibid., pp. 223–224.
[20] Ibid., vol. 1, 1899, pp. 362–363.
[21] Ibid., p. 364.
[22] Ibid., p. 223.
[23] Ibid., pp. 218–219.
[24] Ibid., pp. 219–220.
[25] Ibid., p. 224.
[26] Ibid., pp. 481–482.
[27] Ibid., vol. 1, 1899, pp. 281–282; vol. 1 (a), 1904, pp. 479–481.
[28] Ibid., pp. 273–274.
[29] Ibid., vol., 1(a), 1904, p. 481.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Mingo County:					
Dingess station (near)[1]	2,126				For oil or gas.
Fairfax (northwest of)[2]	1,338				Do.
Monongalia County:					
Amos (4 miles north)[3]	3,174				
Amos (2 miles north)[3]	3,631				
Batelle district[4]	3,001–3,520				6 wells.
Clay district[5]	3,342 3,525				2 wells.
Clay Township	550				Gas.
Crossroads (near)[6]	3,199				
Daybrook (near)[7]	3,276				Oil and water, 2,125 to 2,22; filled up about 1,229 feet.
Fairview district[8]	3,408½				
Flat Run Oil Pool[9]	3,012–3,495				7 wells.
Hoovers Run (just south of).[10]	3,243				
Highland Church (near)[11]	3,484	10–5			Oil well.
Miracle Run Post-Office (1½ miles southeast).[12]	3,170 2,414				2 wells.
Morgantown (3½ miles south).[13]	2,280				Slight flows of oil and gas; near Uffington.
2½ miles west[14]	2,615				
Morgantown[15]	2,267				For oil or gas.
St. Cloud (one-fourth mile northeast).[16]	3,406	10–6½			
St. Leo (near)[17]	3,155				
St. Leo (2 miles west)[18]	3,486	10–6½			Oil at 3,015 and 3,430 feet.
Wadestown (near)[19]	3,090				Oil well.
Do[20]	3,112				Do.
Do[21]	3,300	6½			Gas well.
3 miles west[22]	3,432				
Wordley (near)[23]	2,830–2,960				Do.
Noble County:					
Macksburg (near)[24]	1,695				For oil or gas.
Ohio County:					
Wheeling (near center)[25]					Central Glass Co.'s well.
Wheeling Creek (3 miles above mouth).[26]	2,445				
Wheeling (4 miles southeast).[27]	4,500	4			For oil or gas; temperature at 1,350 feet is 68.75°; at 4,462 feet it is 110.15°; dry; cased to 1,570 feet.
Wheeling[28]	2,095				For oil or gas.
Wheeling (3 miles east-northeast).[29]	2,000				For oil or gas; unsuccessful.
Pleasants County:					
Belmont (near)[30]	587				For oil or gas.
Bens Run station (near)[31]	1,605				
2 miles southeast.[32]	1,940				Oil; "3-barrel well."
Do.[33]	1,900				Oil and gas.
Bens Run (3 miles east)[33]	+ 919				Oil; "about 20-barrel."
Bens Run[34]	+ 947				
Brothers Island[35]	1,348				For oil or gas.
Eureka (near)[36]	+1,348 1,602				2 oil wells.
French Creek (Right Fork)[35]	+ 708				For oil or gas.

[1] Record, W. Va. Geol. Surv. Rept., vol. 1, 1899, pp. 278–280; U. S. Geol. Surv. Folio No. 69, p. 4.
[2] Ibid., pp. 276–277.
[3] Ibid., vol. 1 (a), 1904, pp. 140–141.
[4] Ibid., pp. 143–150.
[5] Ibid., p. 140.
[6] Ibid., pp. 142–143.
[7] Ibid., pp. 135–136.
[8] Ibid., p. 141.
[9] Ibid., p. 136–139.
[10] Ibid., p. 146.
[11] Ibid., vol. 1, 1899, pp. 231–232.
[12] Ibid., vol. 1 (a), 1904, p. 139.
[13] Ibid., pp. 133–134.
[14] Ibid., pp. 134–135.
[15] Record, Pa. 2d Geol. Surv. Rept., Vol. I[5], p. 329.
[16] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, p. 150.
[17] Ibid., pp. 147–148.
[18] Ibid., p. 148.
[19] Ibid., vol. 1, pp. 233–234.
[20] Ibid., pp. 232–233.
[21] Ibid., pp. 230–231; vol. 1 (a), 1904, p. 147.
[22] Ibid., vol. 1 (a), 1904, pp. 148–149.
[23] Ibid., vol. 1, pp. 234–237.
[24] Ibid., pp. 298–299.
[25] W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, p. 230.
[26] Record, ibid., p. 231.
[27] W. Va. Geol. Surv. Rept., vol. 1, pp. 364–365; record of temperatures, Am. Assoc. Adv. Sci. Proc., 1891, p. 258 (description, pp. 446–457); W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, p. 230.
[28] Record, ibid., p. 366; vol. 1 (a), 1904, p. 94.
[29] Record, Pa. 2d Geol. Surv. Ann. Rept., 1886, part 2, pp. 781–782.
[30] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, p. 277.
[31] Ibid., p. 269.
[32] Ibid., p. 272.
[33] Ibid., p. 273.
[34] Ibid., p. 279.
[35] Ibid., p. 280.
[36] W. Va. Geol. Surv. Rept, vol. 1, pp. 351–352; vol. 1 (a), 1904, pp. 280–281.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
:asants County—Cont'd.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Grant district[1]	1,481 2,000	8¼–6¼			2 wells, for oil.
Hebron (near)[2]	2,080				For oil or gas.
Do.[3]	2,012				Do.
Jefferson district[1]	+ 576 + 636 + 623				3 wells, for oil.
Do.[1]	1,470				Oil and gas.
Lafayette district[4]	+2,181 2,750				2 wells; for oil or gas.
Lytton (near)[5]	1,770				For oil or gas.
Maxwell (near)[3]	2,020				Gas at 1,965 feet.
1 mile east[3]	1,779				"5- to 10-barrel well;" oil.
Middle Island Creek[6]	1,932				For oil or gas (C. B. Barker well No. 1).
Iron Bridge[7]	+ 614				For oil or gas.
7 miles from mouth[7]	+ 530				Do.
Parkersburg (5 miles northeast).[8]	2,075				No oil or gas.
Raven Rock (3 miles east).[7]	+ 814				For oil or gas.
St. Marys (6 miles east)[7]	+ 826				
St. Marys (2 miles south)[7]	+ 468 + 480				2 wells, Dotson farm, Nos. 1 and 2.
St. Marys (2½ miles east)[8]	600–1,000	8¼–6¼			Many wells; for oil or gas.
Eliza De Long land[8]	649–996	8¼–6¼			Several wells.
Sugar Creek (3–4 miles from mouth).[7]	+686				For oil or gas.
Union District[9]	1,871				Do.
Waverly (1½ miles east)[1]	1,438				Water, 1,180 to 1,220 feet; gas, 1,413 feet; oil, 1,423 and 1,428 feet.
Township unknown	2,309				Dry.
:ston County:					
Bretz (near)[10]	2,000				For oil or gas; failure.
Henry	703	4¼			
Newburg[11]	3,004				For gas; unsuccessful.
Do	865			18	
tnam County:					
Buffalo (near)	400				
Hurricane (near)[12]	2,198				Gas and oil; neither in paying quantities.
Red House (3 miles north).[12]	1,875	10–4¾			Small show of oil.
Winfield	500				2 wells.
Winfield (1 mile below)[13]	1,670				Oil well.
Winfield (1 mile south)[14]	2,603				For oil or gas.
Winfield (2 miles south)[14]	2,603				Do.
andolph County:					
Beaver Creek (1 mile north).[15]	431				
itchie County:					
Auburn (near)[16]	1,940				Do.
Berea (1 to 2 miles northeast).[17]	1,775–2,062				Several oil wells.
Cabin Run (tollgate well).[18]	2,712				For oil or gas.
Cairo[19]	2,060				Do.
1½ miles northwest[20]	1,735				Do.
4 miles northeast[21]	2,142				Do.
8 miles south[22]	1,652				Small supply of oil.
Vicinity[23]	1,469–2,045				Many wells; for oil and gas.
Cornwallis (vicinity)[24]	1,473–1,657				5 wells; for oil or gas.
Ellenboro (2 miles north).[25]	1,788				Oil well; "5-barrel well."
3½ miles from[26]	1,782–1,828				Several oil and gas wells.
Flannagan Field[27]	1,770–2,120				Many oil and gas wells.

[1] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 904, p. 278.
[2] W. Va. Geol. Surv. Rept., vol. 1, p. 360.
[3] Record, ibid., vol. 1 (a), 1904, p. 275.
[4] Ibid., p. 276.
[5] Ibid., p. 272.
[6] Ibid., pp. 273–274.
[7] Ibid., p. 279.
[8] W. Va. Geol. Surv. Rept., vol. 2, p. 276, 277.
[9] Record, ibid., vol. 1 (a), 1904, p. 273.
[10] W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, p. 342.
[11] Record, ibid., pp. 342–344.
[12] Ibid., p. 483.
[13] W. Va. Geol. Surv. Rept., vol. 2, p. 401; U. S Geol. Surv. Folio No. 72, p. 3.
[14] Record, ibid., vol. 1 (a), 1904, p. 482.
[15] W. Va. Geol. Surv. Rept., vol. 2, pp. 360–361.
[16] Record, ibid, vol. 1 (a), 1904, p. 425.
[17] Ibid., pp. 422–424.
[18] Ibid., p. 406.
[19] W. Va. Geol. Surv. Rept., vol. 1, 1899, p. 302.
[20] Ibid., pp. 303–304.
[21] Ibid., pp. 305–307.
[22] Ibid., pp. 308–309.
[23] Record, ibid., vol. 1 (a), 1904, pp. 430–439.
[24] Ibid., pp. 428–429.
[25] Ibid., p 409.
[26] Ibid., vol. 1, pp. 311–315.
[27] Ibid., vol. 1 (a), 1904, pp. 420–422.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Ritchie County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Harrisville	1,600–2,000				Several oil wells.
Harrisville (near)[1]	2,500				Oil well.
Do.[2]	1,812–2,821				3 wells; for oil or gas.
Harrisville (3 miles south).[3]	1,941				"Dry."
Harrisville (6 miles east)[4]	2,675				
Highland (near)[5]	1,905–2,085				For oil or gas.
Holbrook (near)[6]	2,670				Oil well.
Do.[7]	1,759–2,061				3 wells; for oil or gas.
Lawford (and vicinity)[8]	1,986–2,271				5 wells; for oil or gas.
Macfarlan (near)[9]	1,783–2,326				3 wells; for oil or gas.
Mellin (southeast of)[10]	1,664–1,734				One 5-barrel and two 10-barrel oil wells.
Murphy district (south of Ritchie mines).[11]	1,549–2,068				4 wells; for oil or gas.
Murphy district[12]	2,838				For oil or gas.
Oxford[13]	2,106				Oil well.
1 mile northwest.[4]	2,184				"Fair gas well."
2 miles southwest.[14]	1,646				For oil or gas.
Pensboro (and vicinity)[15]	1,815–2,615				3 wells; for oil or gas.
Petroleum station (3 miles southwest).[16]	1,740				Some oil.
Petroleum station (1¼ miles north).[17]	1,800				Oil well.
Prunty field[18]	1,825–2,134				Several wells; oil or gas.
Pullman (near).[4]	2,128				"Dry."
Ritchie Court-House[19]	1,724–1,918				Several oil and gas wells.
Rush Post-office (near)[20]	1,825				For oil or gas.
Smithville (south of)[21]	1,509, 1,892				2 wells; one "5-barrel."
Union district[22]	2,783				
Whisky Run Pool[23]	1,782–1,829				4 wells for oil or gas.
Whiteoak (near)[24]	2,200, 2,700				2 wells for oil or gas.
1¼ miles south[24]	1,756				"Practically a dry hole."
Wells 1, 3 and 4[25]	1,506–1,910				Miller wells; for oil or gas.
Roan County:					
Geary district	1,479				Oil well.
Do	1,637–3,178				
P. A. Talman farm[26]	1,627				Do.
Roan-Clay county line[27]	1,952	8¼–6¾			Little gas at 1,837 feet.
Spencer (asylum farm)[28]	2,750				For oil or gas.
Spencer (about 10 miles southwest).[29]	1,623–2,362				Several oil and gas wells.
Spencer (about 6 miles east).[30]	1,700–1,951				3 wells for oil or gas; unsuccessful.
Triplett (4 miles southeast).	2,600				Water at 1,525 feet; show of oil at 1,695 feet.
Summers County:					
Crumps Bottom[31]	3,000				Test well for oil or gas.
Taylor County:					
Booth District[32]	2,400				For oil or gas.
Flemington (2 miles north).[33]	2,400				"Dry hole."
1 mile above[34]	3,019¼				Some gas.
Pruntytown (near)[35]	2,680				Do.
Tyler County:					
Alva[36]	2,700				For oil or gas.
Bird Post-Office (near)[37]	2,205				For oil or gas; cave 1,050 and 2,075 feet.
Beech Grove (vicinity)[38]	2,002				For oil or gas.
Booher (1 mile north)[39]	1,867				
Bradin Post-Office (near).[39]	1,915				First gas, 1,830 feet; second gas, 1,905 feet.

[1] W. Va. Geol. Surv. Rept., vol. 1, p. 319.
[2] Record, ibid, vol. 1 (a), 1904, pp. 409–411.
[3] Ibid., p. 416.
[4] Ibid., p. 417.
[5] Ibid., pp. 407–408.
[6] Ibid., vol. 1, p. 320.
[7] Ibid., vol. 1 (a), 1904, pp. 424–425.
[8] Ibid., pp. 427–428.
[9] Ibid., p. 443.
[10] Ibid., p. 441.
[11] Ibid., pp. 442–444.
[12] Ibid., p. 444.
[13] Ibid., vol. 1, pp. 321–322.
[14] Ibid., p. 418.
[15] Ibid., pp. 408–409
[16] Ibid., p. 439.
[17] Ibid., vol. 1, p. 301.
[18] Ibid., vol. 1 (a), 1904, pp. 418–420.
[19] W. Va. Geol. Surv. Rept., vol. 1, pp. 317–318.
[20] Record, ibid., vol. 1 (a), 1904, pp. 439–440.
[21] Ibid., pp. 440–441.
[22] Ibid., pp. 426–427.
[23] Ibid., pp. 411–416.
[24] Ibid., p. 424.
[25] Ibid., pp. 444–445.
[26] W. Va. Geol. Surv. Rept., vol. 2, pp. 398–400
[27] Record, ibid., vol. 1 (a), 1904, pp. 472–473.
[28] Ibid., vol. 1, pp. 264–266.
[29] Ibid., pp. 267–269.
[30] Ibid., vol. 1 (a), 1904, pp. 470–472.
[31] Ibid., pp. 504–505.
[32] Ibid., pp. 338–339.
[33] Ibid., pp. 339–340.
[34] Ibid., pp. 340–342.
[35] Ibid., p. 338.
[36] Ibid., vol. 1, p. 336.
[37] Ibid., vol. 1 (a), 1904, p. 240.
[38] Ibid., pp. 253–254.
[39] Ibid., p. 242.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Tyler County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Centerville and vicinity[1]	1,961–2,199				4 wells; for oil or gas.
Conaway (near)[2]	2,000	8			Capacity, 18,000,000 cubic feet of gas daily.
Doddridge (near)[3]	1,692–2,979				For oil or gas; 13 wells.
Eagle Mills (?) (near)[4]	2,922				Oil well.
Ellsworth district[5]	1,895 1,755				For oil or gas; 2 wells.
Do.[6]	1,919 1,963				Do.
Elk Fork Pool[7]	1,700–2,150				5 wells; for oil or gas.
Falls Mills (2 miles east).[8]	1,926 2,057				2 wells; for oil or gas.
Friendly (3 miles east)[9]	1,620 1,698 1,704				3 wells; for oil or gas; 7 other wells, the records of which are not given.
Gordon Sand Pool (western edge).[10]	2,975 2,818				2 wells; for oil or gas.
Hebron (near)[8]	1,995 2,046				Do.
Hebron region[11]	1,746–2,085				4 wells; for oil or gas.
Indian Creek[12]	1,800–1,921				Do.
Indian Creek (2 miles above mouth).[13]	1,859				Kyle well No. 2.
Kidwell (near)[14]	1,701–1,998				5 wells; for oil or gas.
Little Mills (near)[15]	2,690				For oil or gas.
Long Reach (3¼ miles east).[16]	1,675				Do.
McElroy district[17]	1,870 1,787				2 wells; for oil or gas.
Do.[18]	2,548				
Do.[19]	2,097–2,964				4 wells; for oil or gas.
McKim (near)[20]	1,942				For oil or gas.
1 mile north[21]	2,220				"200-barrel" oil well.
One-half mile north[21]	2,083				"20-barrel" oil well.
Meade district[22]	1,890 1,858 1,704				Oil and gas; 3 wells.
Meadville (4 miles northeast).[21]	1,863				Gas, light, 1,793 feet.
Meadville (1 mile north).[23]	1,762 1,989				2 wells; for oil or gas.
Middlebourne (few miles below).[24]	1,562				Small supply of oil.
4 miles north[25]	1,638				Oil well.
Vicinity[26]	1,647–2,875				4 wells; for oil or gas.
Middle Island Creek[27]	1,643 1,630				2 wells; for oil or gas.
Plum region[28]	1,910–2,023				3 wells; for oil or gas.
Pursley and Kidwell (between).[29]	1,747				For oil or gas.
Ritchie County line (near).[30]	3,049				Do.
Sancho Creek[31]	1,836–1,870				3 wells; for oil or gas.
Sisterville (near)					Large oil well.
2¼ miles southwest[32]	1,865				For oil or gas.
Sisterville field[33]	1,002–1,970				Many wells; for oil and gas.
Union district[34]	1,699	10–6¼			For oil or gas.
Do.[35]	1,743				Do.
Van Camp (near)[17]	1,722				Do.
Wick (near)[36]	1,915				Do.

[1] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 252–253.
[2] Ibid., p. 250.
[3] Ibid., pp. 242–245.
[4] Ibid., vol. 1, pp. 334–335.
[5] Ibid., vol. 1 (a), 1904, pp. 240–241.
[6] Ibid., pp. 249–250.
[7] Ibid., pp. 250–252.
[8] Ibid., p. 256.
[9] Ibid., pp. 266–267.
[10] Ibid., pp. 246–247.
[11] Ibid., pp. 261–262.
[12] Ibid., pp. 241–242.
[13] Ibid., vol. 1, p. 358.
[14] Ibid., vol. 1 (a), 1904, pp. 249–250, 252.
[15] W. Va. Geol. Surv. Rept., vol. 1, p. 335.
[16] Record, ibid., vol. 1 (a), 1904, p. 266
[17] Ibid., p. 240.
[18] Ibid., p. 241.
[19] Ibid., pp. 244, 246 and 247.
[20] Ibid., vol. 1, p. 359.
[21] Record, ibid., vol. 1 (a), 1904, p. 253.
[22] Ibid., pp. 260–261.
[23] Ibid., p. 257.
[24] W. Va. Geol. Surv. Rept., vol. 1, p. 361
[25] Ibid., p. 360.
[26] Record, ibid., vol. 1 (a), 1904, p. 248.
[27] Ibid., pp. 255–256.
[28] Ibid., p. 254.
[29] Ibid., p. 268.
[30] Ibid., p. 259.
[31] Ibid., p. 255.
[32] Ibid , vol. 1, p. 357.
[33] Ibid., vol. 1 (a), 1904, pp. 262–265.
[34] Ibid., p. 250.
[35] Ibid., pp. 267–268.
[36] W. Va. Geol. Surv. Rept., vol. 1, p. 359.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Tyler County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Wick (2 miles south) [1]	2,101				Oil well.
Wick (near) [2]	1,254–1,932				3 wells; for oil or gas.
Wilbur (one-half mile south). [3]	1,972				For oil or gas.
South Penn Oil Co. [4]	2,728–3,139				6 wells; for oil or gas.
Upshur County:					
Buckhannon	2,530				For oil.
Just northeast [5]	2,497				Some oil and gas shown.
Sago (near station) [6]	2,025				Showing of gas.
Wayne County:					
Big Sandy River (near Blaine Creek mouth). [7]	1,845				Gas.
Catlettsburg (1½ miles south). [8]	2,132				For oil or gas.
Twelvepole Creek (Arkansas Branch mouth). [9]	1,968				
Webster County:					
Cleveland (2 miles below). [10]	1,807	6¼			For oil or gas; salt water at 1,125 feet.
Witzel County:					
Brash Township	3,053				Gas.
Brink (near) [11]	2,611				Water at 2,080 feet; gas at 2,470; oil at 2,556.
Do. [12]	2,753				For oil or gas.
Burton (1 to 2 miles east and northeast). [13]	2,263–3,985				8 wells; for oil or gas.
Center district [14]	3,083				45-barrel well.
Church district	2,265–2,971				3 gas wells; 1 dry.
Clay district	2,016–3,375				Gas; some oil.
Dean (1 mile southeast) [15]	3,157				
Dulany (near) [16]					200 to 300 barrels of oil.
Eastern Wetzel [17]	2,050–3,273				4 wells.
Do. [18]	2,043 2,847				2 wells; authority, South Penn Oil Co.
Folsom	3,560	10–5			Deepest producing well known; 100 barrels daily.
1 to 2 miles from [19]	3,053–3,451				For oil and gas.
Grant district [20]	3,195				Gas well.
Do. [21]	2,939 2,748				2 wells.
Do. [22]	2,859				
Do. [23]	3,159 2,682				Do.
Do. [24]	3,044				Gas well.
Do	2,808–3,540				Gas and oil.
Do. [25]	2,642				For oil or gas.
Do. [26]	2,146–3,317				Do.
Green district	2,772–3,136				3 gas wells; 1 well dry.
Hundred (near) [27]	3,249				Gas well.
Jacksonburg (3 miles northeast). [28]	1,838–3,067				
1 mile southeast [29]	2,297–2,697				5 wells.
—— [30]	2,590				
Near [31]	2,571 2,605				2 wells.
Keough	2,635	13–6			Gas well.
Do	3,200	10–6¼			Gas well; salt water 1,935 feet.
Littleton (1 to 2 miles south and southwest) [32].	2,972–3,377				5 wells; for oil or gas.
Lot (near) [33]	2,588				For oil or gas
Magnolia district [34]	2,843				
Moberly (near) [21]	2,002				Gas.

[1] Record, W. Va. Geol. Surv. Rept., vol. 2, pp. 390–392.
[2] Ibid., vol. 1 (a), 1904, pp. 254, 259.
[3] Ibid., p. 251.
[4] Ibid., pp. 244, 246–247.
[5] Ibid., pp. 349–351.
[6] Ibid., pp. 351–353.
[7] Ibid., pp. 498–499.
[8] Ibid., p. 497.
[9] U. S. Geol. Surv. Folio No. 69, p. 4.
[10] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 393–394.
[11] Ibid., p. 183.
[12] Ibid., vol. 1, p. 345.
[13] Ibid., vol. 1 (a), 1904, pp. 176–179.
[14] Ibid., pp. 202–203.
[15] Ibid., p. 203.
[16] W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, p. 201.
[17] Record, ibid., pp. 191–192.
[18] Ibid., pp. 196–197.
[19] Ibid., pp. 184–186.
[20] Ibid., pp. 183–184.
[21] Ibid., p. 189.
[22] Ibid., p. 190.
[23] Ibid., p. 191.
[24] Ibid., vol. 1, pp. 340–342.
[25] Ibid., vol. 1 (a), 1904, p. 192.
[26] Ibid., 193–197.
[27] W. Va. Geol. Surv. Rept., vol. 1, p. 349.
[28] Record, ibid., vol. 1 (a), 1904, pp. 197–198.
[29] Ibid., pp. 198–200.
[30] Ibid., p. 199.
[31] Ibid., p. 200.
[32] Ibid., pp. 181–183.
[33] Ibid., vol. 1, p. 339.
[34] Ibid., vol. 1 (a), 1904, p. 213.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Fitzel County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Pine Grove (3 miles northeast).[1]	3,011				Oil; 150-barrel well.
4 miles northeast[1]	3,460				
Near[1]	2,822				
Piney Fork[2]	2,640				For oil or gas.
Do.[3]	2,040–3,187				20 wells; for oil and gas.
Proctor district[4]	2,100–2,980				5 wells; for oil or gas.
Reader Post-Office (1½ miles southwest).[5]	3,037				
Robinsons Mill (1½ miles east).[6]	3,105				
Silver Hill (near)[7]	2,710				Upper Freeport coal at 575 feet.
Sincerity (1 mile northwest).[8]	3,211				Good gas well
1 mile southwest[8]	3,064				
1½ miles southeast[8]	3,496				Dry hole.
1½ miles north[8]	3,386				Oil and gas.
Smithfield (1 mile northeast).[9]	3,092				
Smithfield region[9]	1,120–3,106				
Smithfield (near)[10]	3,282				Oil well.
2 miles northeast[11]	3,106				Do.
Uniontown (2 miles east).[12]	3,293				
Willey Fork (between Sincerity and Coburn).[13]	2,781				Fair gas well.
Wileyville (2 miles northeast).[14]	3,067				Gas and oil at 3,048 feet; second pay at 3,059 feet.
2½ miles east[14]	3,358				12-barrel well; oil.
1½ miles northeast[15]	3,157				15-barrel well; oil.
	3,116				20-barrel well; oil.
3 miles east[16]	3,228				
	3,270				10-barrel well; oil.
4 miles northeast[17]	3,162				20-barrel well; oil.
	3,413				
Township unknown	2,777–3,010				3 wells; gas and oil.
—[18]	2,900				
—[18]	2,720–2,801				3 wells.
—[18]	3,392				
Wirt County:					
Burning Springs (near)[19]	2,010				Oil well.
Do.[20]	428–1,128				3 oil wells.
Devers Forks[21]	1,480				
Elizabeth (4½ miles east)[22]	2,380				
6 miles west-southwest).[23]	2,806				Dry.
9 miles west-southwest).[24]	2,802				Do.
Munday (1½ miles southwest).[22]	2,205				Oil well.
Northwest corner of Wirt.[25]	1,902				2 oil wells.
	1,795				
Wood County:					
Chesterville (near)[26]	2,172				For oil or gas.
Hendershot field[27]	2,145–2,332				Many wells for oil or gas.
Kanawha Station (near)[28]	2,206				For oil or gas.
Murphytown (vicinity)[29]	2,177				Do.
Do.[30]	2,200–2,365				Several wells for oil or gas.
Parkersburg (near)[31]	2,035				For oil or gas.
5 miles northeast[32]	3,016				Do.
4 miles east[33]	2,230				Do.

[1] Record, W. Va. Geol. Surv. Rept., vol. 1 (a), 1904, pp. 205–206.
[2] W. Va. Geol. Surv., Rept., vol. 1, p. 337.
[3] Record, ibid., vol. 1(a), 1904, pp. 206–211.
[4] Ibid., pp. 212–213.
[5] Ibid., p. 211.
[6] Ibid., p. 184.
[7] Ibid., pp. 200–201.
[8] Ibid., pp. 180–181.
[9] Ibid., pp. 186–189.
[10] W. Va. Geol. Surv., Rept., vol. 1, p. 343.
[11] Ibid., pp. 343–344.
[12] Record, ibid., vol. 1(a), 1904, p. 200.
[13] Ibid., p. 201.
[14] Ibid., p. 202.
[15] Ibid., p. 203.
[16] Ibid., p. 204.
[17] Ibid., pp. 204–205.
[18] Ibid., pp. 189–193; authority, South Penn Oil Co.
[19] W. Va. Geol. Surv. Rept., vol. 1, pp. 262–263; vol. 1 (a), 1904, pp. 463–464.
[20] Record, ibid., vol. 1 (a), 1904, p. 464.
[21] Ibid., pp. 465–466.
[22] Ibid., p. 467.
[23] Ibid., pp. 467–468.
[24] Ibid., p. 468.
[25] Ibid., pp. 466–467.
[26] Ibid., p. 462.
[27] Ibid., pp. 452–455.
[28] Ibid., pp. 447–448.
[29] W. Va. Geol. Surv. Rept., vol. 1, pp. 292–294.
[30] Record, ibid., vol. 1 (a), 1904, pp. 456–457.
[31] W. Va. Geol. Surv. Rept., vol. 1, p. 285.
[32] Ibid., pp. 296–298.
[33] Record, ibid., vol. 1(a), 1904, pp. 460–461.

WEST VIRGINIA—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Wood County—Continued.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Redhill Post-Office (one-half mile northeast).[1]	2,273				For oil or gas.
Tygarts district[2]	3,000				Do.
Union district[3]	2,042–2,393				Many wells for oil or gas.
Vienna station (near)[4]	1,924				For oil or gas.
Volcano (near)[5]	640 1,438				2 wells for oil or gas.
Waverly (6 miles south)[6]	2,261–2,208				Two oil wells.
Waverly (near)[7]	2,310	10–6¼			For oil or gas.
Williamstown (1½ miles below).[8]	1,504–1,673				Do.
4 miles below[9]	710–1,138				2 oil wells.
3 miles above[10]	1,948				For oil or gas.
1½ miles south[11]	1,673				Do.
Charleston Township	1,840				
——	700 1,675 2,608				3 wells.

[1] Record, W. Va., Geol. Surv. Rept., vol. 1 (a), 1904, pp. 459–460.
[2] Ibid., pp. 461–462.
[3] Ibid., pp. 448–452.
[4] Ibid., p. 459.
[5] Ibid., pp. 446–447.
[6] W. Va. Geol. Surv. Rept., vol. 1, pp. 292–294.
[7] Ibid., vol. 1 (a), 1904, p. 452.
[8] W. Va. Geol. Surv. Rept., vol. 1, pp. 290–291.
[9] Ibid., p. 289.
[10] Record, ibid., vol. 1 (a), 1904, pp. 457–458.
[11] Ibid., pp. 458–459.

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WISCONSIN.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
Brown County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Askeaton	534	4¼	7	− 75	
Greenbay	950		70	+ 14	Temp., 53°; several wells.
West Depere	810	5	250	+ 26	Temp., 65°.
Buffalo County:					
Urne	471	6			
Calumet County:					
Sherwood	1,035				
Columbia County:					
Kilbourn	1,320				
Crawford County:					
Prairie du Chien[1]	960	8–5¼	600	+ 60	Temp., 56°; water slightly salty; brine at 514 feet; several wells.
Dane County:					
Madison	736–821	10	Many.	+ 5¼	Several wells; temp., 51°.
Do	700				2 wells.
Stoughton	1,009				
Door County:					
Tornado	1,040	8–6	Many.	− 122	
Douglas County:					
Superior	927	6			Water brackish.
Fond du Lac County:					
Fond du Lac	750	10	Many.	− 10	2 wells.
Do	600	10	Many.	− 10	Do.
Do	480	10	Many.	− 10	
Do.[2]	425				
Waupun	800	6–5			

[1] Record, Wis. Geol. Surv. Rept., 1873–1879, vol. 4, pp. 61–62.
[2] Ibid., 1873–1877, vol. 2, p. 153.

WISCONSIN—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
rant County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
Cassville	1,100	6	Many.	Flows.	
Millville	487	7	Several.	−369	
Patch Grove	487	9–6	Several.	−440	Good water; 2 other similar wells in vicinity.
Platteville	1,000				
reen County:					
Brodhead	1,000	4–8	Each 150	+ 12	2 wells; water from 250 to 300 feet mainly; granite, 700 to 1,000 feet; temp., 52°.
Monroe	+400				
reen Lake County:					
Berlin	425	6	40	+ 3	Temp., 52°.
Do	450		40	+ 3	
efferson County:					
Palmyra[1]	750			− 14	Water at 263 feet; oil at 257 feet.
Watertown	1,145	9	600	+ 11	Temp., 47°.
uneau County:					
Elroy	500 or 600			No flow.	Not in use.
Do	900				
Kenosha County:					
Bristol	815	5		− 32	
Kenosha	1,805				
a Crosse County:					
La Crosse[2]	573	6	100	− 16	Some lime and iron; city supply.
Onalaska	450		284	To surface.	
Manitowoc County:					
Two Rivers	1,700	8	Many.	No flow.	Abandoned; granite in bottom.
Marinette County:					
Marinette	716	4	Many.	+ 21	Water at 405 and 415 feet only; granite at 716 feet; temp., 49°.
Menomonee Falls	1,700	8	Many.	Nearly to top.	
Milwaukee County:					
Milwaukee[3]	1,048	4	Many.	+ 60	
Milwaukee (near)[4]	1,200		300	+ 50	
Do	940–1,700				11 wells.
Monroe County:					
Oil City[5]	510		Many.	+ 25	Main body of water at 300 feet.
Tomah[6]	492			No flow.	
Do	600				
Oconto County:					
Oconto	±400		450	+ 24	Temp., 50°.
Outagamie County:					
Appleton	600				
Combined Locks	790				
Dale	490		Many.	− 15	
Kaukauna	629 643				2 wells.
Pepin County:					
Durand	550	6	180	+ 35	Good water.
Durand (5 miles southeast)	402	10–6	2	−282	Do.
Pierce County:					
River Falls	500	8–6	200	− 6	No water below 400 feet.
Do	400	8–6	200	− 6	
Rockelm	520	8		−120	Abandoned.
Racine County:					
Burlington	1,000	9	Many.	Flows	
Do	800	9	Many.	− 8	
Racine	1,500 1,609				2 wells.
Racine[7]	1,240		Many.	+ 65	Several wells.
Do	1,350	4	Many.	+ 92	
Richland Center	750	6	2,400	11	
Western Union Junction.[8]	1,263		Few	− 40	
Rock County:					
Clinton	650		Many.	− 30	
Janesville[9]	1,100–1,033	8	500	+ 35	2 wells and magnesia water to +48 at 683 feet.
Janesville (fair ground)	+1,100		Not any.	No flow	Abandoned.

[1] Record, Wis. Geol. Surv. Rept., 1873-1877, vol. 2, pp. 161-162.
[2] Ibid., 1873-1879, vol. 4, pp. 60-61
[3] Ibid., 1873-1877, vol. 2, p. 164.
[4] Analysis, ibid., p. 164.
[5] Record, ibid., 1873-1879, vol. 4, pp. 59-60.
[6] Ibid., p. 60.
[7] Ibid., 1873-1877, vol. 2, p. 163.
[8] Ibid., pp. 162-163.
[9] Ibid., p. 153.

WISCONSIN—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
St. Croix County:					
Hudson	400-500				
Sheboygan County:					
Haven	600			− 40	
Do	420			− 11	
Sheboygan[1]	1,475	4	225	+104	Temp., 59°; flow a feet.
Trempealeau County:					
Independence	438			− 12	Well in bad order; doned.
Vernon County:					
De Soto	466	6	126	+ 26	Temp., 52°.
Genoa	460	6	200	− 30	
Walworth County:					
East Troy	2,200			No flow.	
Elkhorn	1,050	8-6	Many.	−155	
Whitewater	950		200	+ 20	
Washington County:					
Hartford	920		40		To be deepened.
Westbend	1,500		Many.	− 4	
Waukesha County:					
Waukesha	1,000-1,500			− 35	Several wells.
Winnebago County:					
Oshkosh[2]	961	6	Many.	− 4	Granite below 700 f
Do	700				
Do.[2]	695	6	Many.	− 1	Granite below 665 f
Do	537	5	Many.	− 1	
Oshkosh (normal school)	613	5	Many.	− 4	
Oshkosh	505	5	Many.	− 1	Several other wells.

[1] Record and analysis, Wis. Geol. Surv. Rept., 1873-1877, vol. 2, , p. 164.

[2] Record, ibid., p. 156.

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WYOMING.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
	Feet.	*Inches.*	*Gallons.*	*Feet.*	
Albany County:					
Jerome[1]	520				
Judson	540		Few.	Flows.	Sulphur water.
Laramie	1,015		30	Flows.	Good water.
Do	1,470				
Leach	510	5		No flow.	
Oxford Ranch	540		Few.	Flows.	For oil; unsuccessf
Carbon County:					
Rawlins	450	4½	200		Several wells.
Do	487		400	Flowed originally.	
Do	928		350	Flowed originally.	Water from 466 fee
Converse County:					
Douglas	500			+ 20	Some oil; much w
Crook County.					
Aladdin	+1,000				No water.
Do.	1,150				
Croton	803				
Felix	1,080				
Gillette	865			−185	
Moorcroft (8 miles northwest).	1,300				For oil, unsuccessf
Moorcroft (10 miles northwest).	800				2 small oil wells.
Rozet	883				
Fremont County:					
Dallas	800-1,200			Flow.	Oil wells.
Mullen	1,200		Several.		Oil and sulphur w
Johnson County:					
Sussex	1,300		Few.		Water at 358 and 1,

[1] Analysis, U. S. Geol. Survey, 21st Ann. Rept., 1889-1890, part 4, p. 571.

WYOMING—Continued.

Location.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
nie County:	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	
heyenne	1,145				
ort D. A. Russell	800				No water below surface supplies.
ɔna County:					
il City [1]	1,130				Oil and gas.
alt Creek Oil Field [2]	809–1,200				Oil wells.
dan County:					
learmont	700			−100	Moderate supply of water.
heridan	500	2½	½		
erona	540			−100	Do.
twater County:					
lmond	1,000				Strong sulphur water.
ock Springs (6 miles south).	2,400	13			Water-bearing beds at 30 and 90 feet; small showing of oil at 625 feet.
'amsutter	1,363				
ı County:					
vanston	1,200	14–10		+½	
illiard	484				For oil; unsuccessful.
ɔn County:					
ambria [3]	2,345				
lifton (north of) [4]	1,002		Few.	Flows.	Mineral water.
ɛrome Siding (on Burlington and Missouri River R. R.).	520				
ewcastle	1,950		Several.	Flows.	For oil; unsuccessful.
Do	1,340				Some oil at about 400 feet.
Do	420				Some oil.
ewcastle (3½ miles southwest).	720				No product.
ewcastle (1½ miles southwest).	650				Large supply of water.
hornton	980			No flow.	Satisfactory supply for railroad use.

[1] ɛcord, etc., Wyo. Geol. Ann. Rept., 1888, p. 32.
[2] ɛcord, Wyo. Univ. Bull. No. 1 (Petroleum), 1896, pp. 18–19.
[3] Record, U. S. Geol. Surv., 21st Ann. Rept., 1889–1900, pt. 4, p. 572.
[4] Ibid., p. 571.

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DEPARTMENT OF THE INTERIOR
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CHARLES D. WALCOTT, DIRECTOR

WEIR EXPERIMENTS, COEFFICIENTS, AND FORMULAS

BY

ROBERT E. HORTON

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

WEIR EXPERIMENTS, COEFFICIENTS, AND FORMULAS

BY

ROBERT E. HORTON

WASHINGTON
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WEIR EXPERIMENTS, COEFFICIENTS, AND FORMULAS.

By Robert E. Horton.

INTRODUCTION.

DEFINITIONS OF TERMS.

The word "weir" will be used to describe any structure used to determine the volume of flow of water from measurements of its depth on a crest or sill of known length and form. In this general sense timber and masonry dams having various shapes of section, reservoir overflows, and the like may be weirs. Terms, more or less synonymous, used to describe such weirs are "comb," "wasteway," "spillway," "overwash," "rollway," and "overfall."

The French term "nappe," suggesting the curved surface of a cloth hanging over the edge of a table, has been fittingly used to designate the overfalling sheet of water.

The expression "wetted underneath" has been used to describe the condition of the nappe designated by Bazin as "noyées en dessous," signifying that the water level between the nappe and the toe of the weir is raised by vacuum above the general water level below the weir.

"Thin-edged weir" and "sharp-crested weir" are used to designate a weir in which the nappe, or overfalling sheet, touches only the smooth, sharp upstream corner or edge of the crest, the thickness of which is probably immaterial so long as this condition is fulfilled.

A "suppressed weir" has a channel of approach whose width is the length of the weir crest.

A "contracted weir" has a crest length that is less than the width of the channel of approach.

The term "channel of approach," or "leading channel," defines the body of water immediately upstream from the weir, in which is located the gage by which the depth of overflow is measured.

"Section of approach" may refer to the cross section of the leading channel, if the depth and width of the leading channel are uniform; otherwise it will, in general, apply to the cross section of the channel of approach in which the gage is located.

"Weir section" refers to the cross section of the overflowing stream in the plane of the weir crest.

"Crest contraction" refers to the diminished cross section of the overflowing stream resulting from the upward curvature of the lower water filaments in passing the crest edge. It does not include the downward curvature of the water surface near the weir crest.

The "vertical contraction of the nappe" includes both the crest contraction and the surface contraction.

"Incomplete contraction" may take place either at the crest or at the ends of a weir, and will occur when the bottom or side walls of the channel of approach are so near the weir as to prevent the complete curvature of the water filaments as they pass the contracting edge.

Dimensions are uniformly expressed in feet and decimals, velocities in feet per second, and quantities of flow in cubic feet per second, unless otherwise stated in the text.

In the preparation of this paper much computation has been involved and it is expected that errors will appear, which, if attention is called to them, may be corrected in the future. Information concerning such errors will be gratefully received.

NOTATION.

The symbols given below are used in the values indicated. The meaning of additional symbols as used and special uses of those that follow are given in the text:

D=Measured or actual depth on the crest of weir, usually determined as the difference of elevation of the weir crest and the water level, taken at a point sufficiently far upstream from the weir to avoid the surface curve.

H=The head corrected for the effect of velocity of approach, or the observed head where there is no velocity of approach. As will be explained, D is applied in formulas like Bazin's, in which the correction for velocity of approach is included in the coefficient. H is applied in formulas where it is eliminated.

v=Mean velocity of approach in the leading channel, usually taken in a cross section opposite which D is determined.

h=Velocity head$=\alpha\frac{v^2}{2g}$.

g=Acceleration by gravity. Value here used 32.16.

P=Height of weir crest above bottom of channel of approach, where channel is rectangular.

W=Width of channel of approach where D is measured.

A=Area of cross section of channel of approach.

G=Area of channel section where D is measured, per unit length of crest.

a=Area of weir section of discharge$=D\,L$.

L=Actual length of weir crest for a suppressed weir, or length corrected for end contractions, if any.

L'=Actual length of crest of a weir with end contractions.

N=Number of complete end contractions.

B=Breadth of crest of a broad-crested weir.

S=Batter or slope of crest, feet horizontal to one vertical.

d=Depth of crest submergence in a drowned or submerged weir.
Q=Volume of discharge per unit of time.
C, M, m, μ, α, f, etc., empirical coefficients.

BASE FORMULAS.

The following formulas have been adopted by the engineers named:

$Q=\frac{2}{3}MLH\sqrt{2gH}.$	Hamilton Smith (theoretical).
$=\mu LH\sqrt{2gH}.$	Bazin, with no velocity of approach.
$=mLD\sqrt{2gD}.$	Bazin, with velocity of approach.
$=CLH^{\frac{3}{2}}.$	Francis [a] (used here).
$=CLH^{\frac{3}{2}}+fL.$	Fteley and Stearns.

EQUIVALENT COEFFICIENTS.

The relations between the several coefficients, so far as they can be given here, are as follows:

$$\mu=\frac{2}{3}M.$$

M is a direct measure of the relation of the actual to the theoretical weir discharge.

$$C=\mu\sqrt{2g}=\frac{2}{3}M\sqrt{2g}=8.02\ \mu=5.35\ M.$$

$$M=\frac{3}{2}\mu=\frac{3}{2}\frac{C}{\sqrt{2g}}=0.1870\ C.$$

$$\mu=\frac{C}{8.02}=0.1247\ C.$$

APPROXIMATE RELATIVE DISCHARGE OVER WEIRS.

For a thin-edged weir, the coefficient C' in the Francis formula is $3.33=\frac{10}{3}$. Let C'' be the coefficient for any other weir, and x the relative discharge as compared with the thin-edged weir, then

$$\frac{10}{3}:C''::1:x$$

$$x=\frac{3C''}{10}\quad\ldots\ldots\ldots\ldots\quad(1)$$

or, as a percentage,

$$x_1=100\ x=30\ C''.$$

[a] The coefficient C of Francis includes all the constant or empirical factors appearing in the formula, which is thus thrown into the simplest form for computation.

This expression will be found convenient in comparing the effect on discharge of various modifications of the weir cross section. For a broad-crested weir with stable nappe, $C_1=2.64$, see p. 121. The discharge over such a weir is thus seen to be 79.2 per cent of that for a thin-edged weir by the Francis formula.

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BAZIN, H., Expériences nouvelles sur l'écoulement en déversoir, 6me art., Annales des Ponts et Chaussées, Mémoires et Documents, 1898, 2me trimestre, pp. 121–264. This paper gives the results of experiments on weirs of irregular section. Bazin's earlier papers, published in Annales des Ponts et Chaussées, 1888, 1890, 1891, 1894, and 1896, giving results of experiments chiefly relating to thin-edged weirs and velocity of approach, have been translated by Marichal and Trautwine.

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THEORY OF WEIR MEASUREMENTS.

DEVELOPMENT OF THE WEIR.

The weir as applied to stream gaging is a special adaptation of mill dam, to which the term weir, meaning a hindrance or obstruction, has been applied from early times. The knowledge of a definite relation between the length and depth of overflow and the quantity also probably antedates considerably the scientific determination of the relation between these elements.

In theory a weir or notch[a] is closely related to the orifice; in fact, an orifice becomes a notch when the water level falls below its upper boundary.

THEOREM OF TORRICELLI.

The theorem of Torricelli, enunciated in his De Motu Gravium Naturaliter Accelerato, 1643, states that *the velocity of a fluid passing through an orifice in the side of a reservoir is the same as that which would be acquired by a heavy body falling freely through the vertical*

[a] Commonly applied to a deep, narrow weir.

height measured from the surface of the fluid in the reservoir to the center of the orifice.

This theorem forms the basis of hydrokinetics and renders the weir and orifice applicable to stream measurement. The truth of this proposition was confirmed by the experiments of Mariotte, published in 1685. It can also be demonstrated from the laws of dynamics and the principles of energy.[a]

ELEMENTARY DEDUCTION OF THE WEIR FORMULA.

In deducing a theoretical expression for flow over a weir it is assumed that each filament or horizontal lamina of the nappe is actuated by gravity acting through the head above it as if it were flowing through an independent orifice. In fig. 1 the head on the successive orifices being H_1, H_2, H_3, etc., and their respective areas A_1, A_2, A_3, etc., the total discharge would be

$$Q = C\sqrt{2g}\left[A_1 H_1^{\frac{1}{2}} + A_2 H_2^{\frac{1}{2}} \text{ to } + A_n H_n^{\frac{1}{2}}\right] \quad . \quad . \quad . \quad . \quad (2)$$

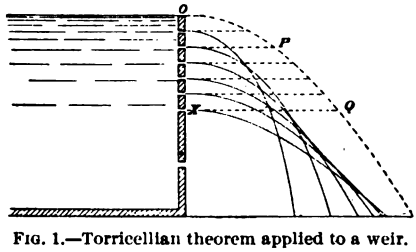


FIG. 1.—Torricellian theorem applied to a weir.

If the small orifices A be considered as successive increments of head H, the weir formula may be derived by the summation of the quantities in parentheses. H comprises n elementary strips, the breadth of each is $\frac{H}{n}$. The heads on successive strips are $\frac{H}{n}$, $\frac{2H}{n}$, etc., and the total becomes

$$Q = \frac{LH}{n}\sqrt{2g}\left(\sqrt{\frac{H}{n}} + \sqrt{\frac{2H}{n}} + \sqrt{\frac{3H}{n}} + \right) \quad . \quad . \quad . \quad . \quad (3)$$

where $\frac{LH}{n} = A + A_1$, etc., for a rectangular weir. The sum of the series $\sqrt{1} + \sqrt{2} + \sqrt{3} +$ to $\sqrt{n} = \frac{2}{3} n^{\frac{3}{2}}$.

Hence the discharge is

$$Q = \frac{LH}{n}\sqrt{2g}\sqrt{\frac{H}{n}} \cdot \frac{2}{3} n^{\frac{3}{2}}.$$

$$= \frac{2}{3} LH\sqrt{2gH}.$$

The above summation is more readily accomplished by calculus.

[a] See Wood, Elementary Mechanics, p. 167, also p. 291.

APPLICATION OF THE PARABOLIC LAW OF VELOCITY TO WEIRS.

The following elementary demonstration clearly illustrates the character of the weir:

According to Torricelli's theorem (see fig. 1), the velocity (v) of a filament at any depth (x) below surface will be $v=\sqrt{2gx}$. This is the equation of a parabola having its axis OX vertical and its origin O at water surface. Replacing the series of jets by a weir with crest at X, the mean velocity of all the filaments will be the average ordinate of the parabola OPQ. The average ordinate is the area divided by the height, but the area of a parabola is two-thirds that of the circumscribed rectangle; hence the mean velocity of flow through the weir is two-thirds the velocity at the crest; i. e., two-thirds the velocity due to the total head H on the crest. The discharge for unit length of crest is the head H, or area of opening per unit length, multiplied by the mean velocity. This quantity also represents the area of the parabolic velocity curve $OPQX$. The mean velocity of flow in the nappe occurs, theoretically, at two-thirds the depth on the crest.

The modification of the theoretical discharge by velocity of approach, the surface curve, the vertical contraction at the crest, and the various forms that the nappe may assume under different conditions of aeration, form of weir section, and head control the practical utility of the weir as a device for gaging streams.

GENERAL FORMULA FOR WEIRS AND ORIFICES.[a]

Consider first a rectangular opening in the side of a retaining vessel. The velocity of flow through an elementary layer whose area is Ldy will be from Torricelli's theorem:

$$v=\sqrt{2gy}.$$

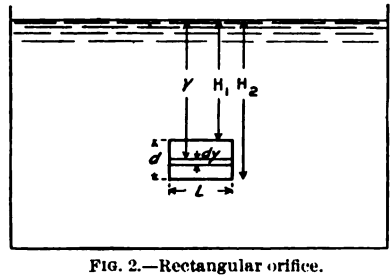


FIG. 2.—Rectangular orifice.

The discharge through the entire opening will be, per unit of time, neglecting contractions,

$$Q=\int_{H_1}^{H_2}\sqrt{2gy}.\,Ldy \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

[a] The correlation of the weir and orifice has been given by Merriman. See Hydraulics, pp. 42–43.

This is a general equation for the flow through any weir or orifice, rectangular or otherwise, Q being expressed as a function of y. In the present instance L is constant. Integrating,

$$Q=\frac{2}{3}L\sqrt{2g}\left(H_2^{\frac{3}{2}}-H_1^{\frac{3}{2}}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

For a weir or notch, the upper edge will be at surface, $H_1=O$, and letting $H_2=H$ in equation (5),

$$Q=\frac{2}{3}L\sqrt{2g}\ H^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

In the common formula for orifices, only the head on the center of gravity of the opening is considered.

Expressing H_2 and H_1 in terms of the depth H on the center of gravity of the opening and the height of opening d, Merriman obtains, after substituting these values in and expanding equation (5) by the binomial theorem, the equivalent formula,

$$Q=dL\sqrt{2gh}\left[1-\frac{1}{96}\frac{d^2}{H^2}-\frac{1}{2048}\frac{d^4}{H^4}-\frac{1}{21845}\frac{d^6}{H^6},\ \text{etc.}\right] \quad . \quad . \quad (7)$$

The sum of the infinite series in brackets expresses the error of the ordinary formula for orifices as given by the remainder of the equation. This error varies from 1.1 per cent when $h=d$ to 0.1 per cent when $h=3d$.

VERTICAL CONTRACTION.

Practical weir formulas differ from the theoretical formula (6) in that velocity of approach must be considered and the discharge must be modified by a contraction coefficient to allow for diminished section of the nappe as it passes over the crest lip. Velocity of approach is considered on pages 14 to 20. Experiments to determine the weir coefficient occupy most of the remainder of the paper. The nature of the contraction coefficient is here described.

Vertical contraction expresses the relation of the thickness of nappe, x, in the plane of the weir crest, to the depth on the crest, H. If the ratio x/H were unity, the discharge would conform closely with the expression

$$Q=2/3\ LH\sqrt{2gH}.$$

The usual coefficient in the weir formula expresses nearly the ratio x/H.

The vertical contraction comprises two factors, the surface curve or depression of the surface of the nappe and the contraction of the under surface of the nappe at the crest edge. The latter factor is

particular will vary with form of the weir cross section, and in general variation in the vertical contraction is the principal source of variation in the discharge coefficient for various forms of weirs.

The usual base weir formula, $Q=2/3\ LH\sqrt{2gH}$, is elsewhere given for an orifice in which the upper edge is a free surface. If instead the depth on the upper edge of the orifice is d, the surface contraction, there results the formula

$$Q=\frac{2}{3}ML\sqrt{2g}\left(H^{\frac{3}{2}}-d^{\frac{3}{2}}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

This is considered as the true weir formula by Merriman.[a] In this formula only the crest-lip contraction modifies the discharge, necessitating the introduction of the coefficient. The practical difficulties of measuring d prevent the use of this as a working formula.

Similarly a formula may be derived in which only the effective cross section s is considered, but even this will require some correction of the velocity. Such formulas are complicated by the variation of s and d with velocity of approach.[b] Hence, practical considerations included, it has commonly been preferred to adopt the convenient base formula for weirs, $Q=\frac{2}{3}\ MLH\sqrt{2gH}$, or an equivalent, and throw all the burden of corrections for contraction into the coefficient M.

VELOCITY OF APPROACH.

THEORETICAL FORMULAS.

Before considering the various practical weir formulas in use some general considerations regarding velocity of approach and its effect on the head and discharge may be presented.

In the general formula (4) for the efflux of water when the water approaches the orifice or notch with a velocity v, then with free discharge, writing $D+h$ in place of H, for a rectangular orifice, we have

$$Q=\int_{D_1+h}^{D_2+h}\sqrt{2gy}\ .\ Ldy \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

D_1 and D_2 being the measured depth on upper and lower edges of the orifice, and $h=\frac{v^2}{2g}$, the velocity head.

To assume that $D+h$ equals H is to assume that the water level is

[a] Hydraulics, p. 123.

[b] See Trautwine and Marichal's translation of Bazin's Experiments, pp. 231–307, where may also be found other data, including a résumé of M. Boussinesq's elaborate studies of the vertical contraction of the nappe, which appeared in Comptes Rendus de l'Académie des Sciences for October 24, 1887.

:reased by the amount h, or, as is often stated, that H is "measured the surface of still water." This is not strictly correct, how-ɜr, because of friction and unequal velocities, which tend to make $-D>h$, as explained below.

For a weir, D_1 equals zero; integrating,

$$Q=\frac{2}{3}L\sqrt{2g}\left[(D+h)^{\frac{3}{2}}-h^{\frac{3}{2}}\right]$$

Since $Q=\frac{2}{3}L\sqrt{2g}H^{\frac{3}{2}}$, we have

$$H=\left\{(D+h)^{\frac{3}{2}}-h^{\frac{3}{2}}\right\}^{\frac{2}{3}} \quad . \quad . \quad . \quad . \quad . \quad (9a)$$

This is the velocity correction formula used by James B. Francis.[a] Since h appears in both the superior and inferior limits of integra-›n, it is evident that h increases the velocity only, and not the sec-›n of discharge. The criticism is sometimes made that Francis's uation has the form of an increase of the height of the section of scharge as well as the velocity.

The second general method of correcting for velocity of approach nsists of adding directly to the measured head some function of the ·locity head, making

$$H=D+\alpha h$$

the formula

$$Q=CLH\sqrt{2gH}$$

$$Q=CL\,(D+\alpha h)\sqrt{2g(D+\alpha h)}. \quad . \quad . \quad . \quad . \quad . \quad 9b$$

This is the method employed by Boileau, Fteley and Stearns, and azin. No attempt is made to follow theory, but an empirical correc-on is applied, affecting both the velocity and area of section.

By either method v must be determined by successive approxima-ons unless it has been directly measured.

Boileau and Bazin modify (9b) so as to include the area of section of hannel of approach, and since the velocity of approach equals Q/A, separate determination of v is unnecessary. Bazin also combines he factor for velocity of approach with the weir coefficient.

The various modifications of the velocity correction formulas are ;iven in conjunction with the weir formulas of the several experi-nenters.

[a] Bovey gives similar proof of this formula for the additional cases of (1) an orifice with free dis-ıarge, (2) a submerged orifice, (3) a partially submerged orifice or drowned weir, thus establishing ›generality.

DISTRIBUTION OF VELOCITY IN CHANNEL OF APPROACH.

The discharge over a weir takes place by virtue of the potential energy of the layer of water lying above the level of the weir crest, which is rendered kinetic by the act of falling over the weir. If the water approaches the weir with an initial velocity, it is evident that some part of the concurrent energy will facilitate the discharge.

The theoretical correction formulas may not truly represent the effect of velocity of approach for various reasons:

1. The fall in the leading channel adjacent to the measuring section is the source of the velocity of approach, and this fall will always be greater than that required to produce the existing velocities, because some fall will be utilized in overcoming friction.

2. The velocity is seldom uniform at all parts of the leading channel and the energy of the water varies accordingly. This effect is discussed later (p. 17).

3. It is not certain just what portion of the energy of the water in the section of the leading channel goes to increase the discharge.

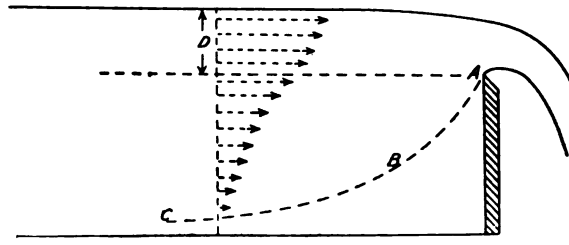


FIG. 3.—Distribution of velocities.

In general the threads of the water in the cross section of the channel of approach to a weir have varying velocities. It follows that, as will be shown, the ratio of the actual energy of the approaching water to the energy due to the mean velocity will be greater than unity, and for this reason the correction for velocity of approach will be greater than if the energy were that due to a fall through a head produced by the mean velocity v. The more nearly uniform is the velocity of the water in the leading channel the smaller will be the necessary coefficient α in the velocity head formula. The velocity may be rendered very nearly uniform by the use of stilling racks or baffles. Where this was done in the experiments on which a formula was based (that of Francis, for example) a larger velocity of approach correction than that obtained by the author may be necessary in applying the formula to cases where there is wide variation in the velocity in the leading channel. To avoid such a contingency it is desirable, when practicable, to measure head to surface of still water, because more accurate results can be obtained and wash against instruments prevented.

The vertical and horizontal velocity curves in an open channel usually closely resemble parabolas. A weir interposes an obstruction in the lower part of the channel, checking the bottom velocities. The velocity is not, however, confined to the filaments in line with the section of the discharge opening of the weir. As a result of viscosity of the liquid, the upper rapidly moving layers drag the filaments underneath, and the velocity may extend nearly or quite to the channel bottom. There will usually, however, be a line (A B C, fig. 3), rising as the weir is approached, below which there is no forward velocity.

The line A B C is the envelope of the curves of vertical velocity in the channel of approach.

There will be a similar area of low velocity at each side of the channel for a contracted weir. The inequality of velocities for such weirs being usually greater than for suppressed weirs, it follows that a larger coefficient in the formula for velocity of approach may be required. This is confirmed by experiment.

Various assumptions have been made as to what portion of the energy of the approaching stream goes to increase the discharge, (*a*) that resulting from the mean velocity deduced from the discharge divided by the area of the entire section of the channel of approach; (*b*) that of the mean velocity obtained by using the sectional area of the moving water, above the line A B C, fig. 3; (*c*) that of the filaments lying in line with or nearest to the section of the weir opening, determined approximately by the surface velocity.[a]

DISTRIBUTION OF ENERGY IN CHANNEL OF APPROACH.

Consider unit width of the channel of approach:

Let v_s = Surface velocity.
v_m = Mean velocity.
v_b = Bottom velocity.
v = Velocity at a height x above bottom.
X = Depth of water in channel of approach.
w = Weight of unit volume.

The general formula for kinetic energy is

$$\text{K. E.} = \frac{Wv^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where W = weight of the moving mass.

If the velocity increases uniformly from bottom to surface, the velocity at height x will be

$$v = v_b + \frac{x}{X}(v_s - v_b).$$

[a] Smith, Hamilton, Hydraulics, p. 68.

Let dx be the thickness of a lamina one unit wide at height x. The total kinetic energy for the depth X will be

$$\text{K. E.} = \int_0^X \left(v_b + \frac{x}{X}(v_s - v_b)\right)^3 \frac{w}{2g}\, dx \quad . \quad . \quad . \quad . \quad (11)$$

If the velocity is uniform, the total kinetic energy per unit width is found by integration to be

$$\text{K. E.} = \frac{wXv_m^3}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Integrating for the simple case where $v_b = 0$ and the velocity increases uniformly from the bottom to the surface so that $v_m = \frac{v_s}{2}$, we have

$$\text{K. E.} = \frac{wXv_m^3}{g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

Comparing this with the expression for kinetic energy of a stream flowing with the uniform velocity v (formula 12), we find the mass energy of the stream with uniformly varying velocity to be twice as great as for the uniform velocity.

By a similar integration the ratio of the total kinetic energy to the kinetic energy corresponding to the mean velocity in the channel of approach can be obtained for any assumption as to the distribution of velocities in the leading channel. The resulting ratio will depend upon the relative areas of section with low and high velocities which go to make up the mean, and in practice it will generally exceed unity.

The lowering of the water surface from the level of a still pond will also be greater in the case of unequal velocities than in the case of a uniform velocity equal to their mean. The theoretical weir formula indicates the same discharge in case of a uniform velocity of approach v as in case of varying velocities whose mean is equal to v, although in the former case the actual drawing down of the head if it were measured would be found greater. If h were the velocity head corresponding to the mean velocity, and if v_1, v_2, v_3, etc., v_n were the actual velocities in the n unit areas of cross section, the actual velocity head h' will be such that

$$\frac{Qw}{2g}(v_1^2 + v_2^2 + \text{etc. } v_n^2) = wQh' = \text{Integral K. E.}$$

Now,

$$\frac{wQ}{2g} v^2 = wQh = \text{K. E. of average velocity.}$$

As shown above, the integral K. E. is the greater.

It follows that $h'>h$.

If $$\alpha=\frac{h'}{h}$$

Then $$h'=\alpha h.$$

Introducing velocity of approach in the discharge formula we substitute $D+h$ for H, and integrate between the limits zero and D. Hence, for the same discharge, the area of weir section is greater without velocity of approach by nearly the amount hL.

For a given measured head D, the effect of velocity of approach, whatever it may be, appears as an increase in the mean velocity of discharge in the plane of the weir. The relation of the mean velocity of discharge for a weir with velocity of approach to that for a weir without such velocity is shown by the following expression, the mean head being the same in both cases:

Mean velocity in the plane of the weir $=\frac{Q}{D}$,

then $$\frac{Q}{D}:\frac{Q_1}{D}::D^{\frac{3}{2}}:(D+h)^{\frac{3}{2}}-h^{\frac{3}{2}}.$$

It will be seen that the discharge over a weir with velocity of approach is less than that for the same total head and greater than that for the same measured head without velocity of approach, and that with a given measured head the greater the velocity of approach the greater will be the discharge.

In a weir section opening out of still water there is always a considerable surface velocity, the parabolic law (see fig. 3) being modified by fluid friction, which tends to equalize the velocities. Velocity of approach, being usually greater at the surface, furthers this equalization. Some of the kinetic energy of the swifter-moving filaments is transferred to their slower-moving neighbors, the result being that while the kinetic energy of the whole mass Q passing the weir per second remains constant, yet the *average* velocity is accelerated and the discharge rate is increased as compared with the theoretical quantities. This will be clearer if we consider two contiguous filaments, each having unit section a, one with a velocity of 1, the other of 2 feet per second. The two will discharge 2+1 units flow per second, having the total kinetic energy indicated below:

$$\text{K. E.}=\frac{1\times1^2}{2g}aw+\frac{2\times2^2}{2g}aw=9\frac{aw}{2g}.$$

If, now, the velocities are equalized, 9 units of kinetic energy will be equally divided between the two filaments, so that, the new velocity being v,

$$\frac{2awv \times v^2}{2g} = \frac{9aw}{2g},$$

and

$$v = \sqrt[3]{\frac{9}{2}} = 1.651.$$

The average velocity before equalization was 1.5.

The discharge from two filaments having equal velocities will be 3.302 units, as compared with 3.00 for two filaments having unequal velocities.

THE THIN-EDGED WEIR.

EARLIER EXPERIMENTS AND FORMULAS.

Prior to 1850 the practice of weir measurement was in a somewhat chaotic condition, especially in England, Germany, and the United States. There were many experimental results, but the experiments were made on so small a scale that the various influences affecting the measurements and the lack of proper standards made the results erratic and untrustworthy in detail. Greater advancement had been made in France by such savants as Dubuat, Eytelwein, D'Aubuisson, Castel, Poncelet, Lesbros, and Boileau. Some of the work of the early French experimenters has proved, in the light of wider experience, to be of considerable value.

EXPERIMENTS OF CASTEL.

The first experiments deserving consideration are of those of M. Castel, conducted at the waterworks of Toulouse in 1835 and 1836.[a] Castel erected his apparatus on a terrace in conjunction with the water tower, which received a continuous supply of 1.32 cubic feet per second, capable of being increased to 1.77 cubic feet per second. The weir consisted of a wooden dam, surmounted by a crest of copper 0.001 foot in thickness, situated in the lower end of a leading channel, 19.5 feet long, 2.428 feet wide, and 1.772 feet deep. Screens were placed across the upper end of the channel to reduce oscillations. The head was measured at a point 1.60 feet upstream from the weir by means of a point gage. The overflow was measured in a zinc-lined tank having a capacity of 113.024 cubic feet. The length of the crest for weirs with suppressed contractions varied from 2.393 to 2.438 feet. Heights of weirs varying from 0.105 to 0.7382 were used, and

[a] Originally published in Mémoires Acad. Sci. Toulouse, 1837. See D'Aubuisson's Hydraulics, Bennett's translation, pp. 74-77. Data recomputed by Hamilton Smith in his Hydraulics, pp. 80-82 and 138-145. The recomputed coefficients will be found valuable in calculating discharge for very small and very low weirs.

· series of experiments was performed on suppressed weirs
:et long. The head varied for the longer weirs from about
.25 foot. Additional experiments were made on contracted
/ing various lengths, from 0.0328 to 1.6483 feet, in a channel
t wide, and for lengths from 0.0328 to 0.6542 foot in a chan-
3 feet wide. The experiments on these narrow slit weirs
depths varying from 0.1 or 0.2 foot to a maximum of about

uisson gives the following formula, derived from the experi-
Castel for a suppressed weir:

$$Q=3.4872LD\sqrt{D}+0.035\,W^2 \quad . \quad . \quad . \quad . \quad . \quad (14)$$

$^{\prime}$ is the measured central surface velocity of approach, ordi-
out $1.2v$.

EXPERIMENTS OF PONCELET AND LESBROS.

:periments made by Poncelet and Lesbros, at Metz, in 1827
, under the auspices of the French Government, were contin-
esbros in 1836. The final results were not published, how-
il some years later.[a]

periments of Poncelet and Lesbros and of Lesbros were per-
:hiefly on a weir in a fixed copper plate, length 5.562 feet.
was measured in all cases in a reservoir 11.48 feet upstream,
he influence of velocity of approach. The crest depth varied
ut 0.05 to 0.60 or 0.80 foot. The experiments of Lesbros
ole from the fact that a large number of forms of channel of
were employed, including those with contracted and con-
ides, elevated bottoms, etc. The experiments of Lesbros on
cial forms of weirs have been carefully recomputed by Ham-
ith, and may be useful in determining the discharge through
/ing similar modifications.[b]

EXPERIMENTS OF BOILEAU.

periments of Boileau[c] at Metz, in 1846, included 3 suppressed
ving lengths and heights as follows:
ngth 5.30 feet, height 1.54 feet.
ngth 2.94 feet, height 1.12 feet.
ngth 2.94 feet, height 1.60 feet.
epth of overflow varied from 0.19 to 0.72 foot. Boileau
the following formula for a suppressed weir:

$$Q=3.3455\,\frac{P+D}{\sqrt{(P+D)^2-D^2}}\,LD^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad (15)$$

Expériences hydrauliques sur les lois de l'écoulement de l'eau, Paris, 1852.
Smith, Hamilton, Hydraulics, pp. 96 and 97 and 104–107. Also plates 1–2 and 8.
Jaugeage de cours d'eau, etc., Paris, 1850.

This formula includes the correction for velocity of approach. The coefficient C, it will be noticed, is given as a constant. Boileau afterwards gave a table of corrections varying with the depth, indicating a discharge from 96 to 107 per cent of that obtained with the constant coefficient. Additional experiments by Boileau on suppressed weirs having a crest length of about 0.95 foot have been recomputed by Hamilton Smith.[a] The heights of weirs were, respectively, 2.028, 2.690, 2.018, and 2.638 feet. In these experiments the discharge was determined by measurement through orifices.

EAST INDIAN ENGINEERS' FORMULA.[b]

The East Indian engineers' formula for thin-edged weirs is

$$\left.\begin{aligned} Q&=\frac{2}{3}\,ML\sqrt{2gH^3}=CLH^{\frac{3}{2}} \\ \text{where}\quad C&=\frac{2}{3}\sqrt{2g}\;M=5.35\;M \\ M&=1-\left(\frac{0.04\,[34.6+H]}{4}\right). \end{aligned}\right\}\quad\ldots\ldots\quad(16)$$

Reducing,

$$\left.\begin{aligned} M&=0.654\;-0.01\;H \\ C&=3.4989-0.0535\;H \end{aligned}\right\}\quad\ldots\ldots\quad(17)$$

This formula applies to a suppressed weir. Method of correction for velocity of approach is not stated. Coefficient M has a maximum value 0.654, and decreases slowly as the head increases. Limits of applicability of formula are not stated. Values of C are given below:

Coefficient C for thin-edged weirs, East Indian engineers' formula.[c]

H in feet.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	3.499	3.494	3.488	3.483	3.478	3.472	3.467	3.462	3.456	3.451
1	3.445	3.440	3.435	3.429	3.424	3.419	3.413	3.408	3.403	3.397
2	3.392	3.386	3.381	3.376	3.370	3.365	3.360	3.354	3.349	3.344
3	3.338	3.333	3.328	3.322	3.317	3.312	3.306	3.301	3.296	3.290
4	3.285	3.280	3.274	3.269	3.264	3.258	3.253	3.248	3.242	3.237
5	3.221	3.226	3.221	3.215	3.210	3.205	3.199	3.194	3.189	3.183
6	3.178	3.172	3.167	3.162	3.156	3.151	3.146	3.140	3.135	3.130
7	3.124	3.119	3.114	3.108	3.103	3.098	3.092	3.087	3.082	3.076
8	3.071	3.066	3.060	3.055	3.050	3.044	3.039	3.034	3.028	3.023
9	3.017	3.012	3.007	3.001	2.996	2.991	2.985	2.980	2.975	2.969

[a] Hydraulics, pp. 133-135.

[b] Given in J. Mullins's Irrigation Manual, introduced in United States by G. W. Rafter and used in region of upper Hudson River. Not given in Bellasis's recent East Indian work on hydraulics.

[c] For East Indian engineers' broad-crested weir formula, using coefficients derived from the above, see p. 114.

EXPERIMENTS AND FORMULA OF JAMES B. FRANCIS.

The experiments on discharge over thin-edged weirs,[a] upon which the Francis formula is based, were made in October and November, 1852, at the lower locks of the Pawtucket canal, leading from Concord River past the Lowell dam to slack water of Merrimac River. Additional experiments were made by Francis in 1848[b] at the center vent water wheel at the Boott Cotton Mills in Lowell, with gates blocked open and with constant head. A uniform but unknown volume of water was thus passed through the turbine and over a weir having various numbers of end contractions, the effect of which was thus determined. Similar experiments were made in 1851 at the Tremont turbine,[c] where a constant volume of water was passed over weirs of lengths ranging from 3.5 to 16.98 feet and with from two to eight end contractions. These experiments were made to determine the exponent n in the weir formula

$$Q = CLH^n.$$

Francis here found $n=1.47$, but adopted the value $n=1.5=3/2$, in the experiments of 1852.

The Pawtucket canal lock was not in use at the time of the Lowell experiments in 1852 and the miter gates at the upper lock chamber were removed and the weir was erected in the lower hollow quoin of the gate chamber. The middle gates at the foot of the upper chamber were replaced by a bulkhead having a sluice for drawing off the water. A timber flume in the lower chamber of the lock was used as a measuring basin to determine the flow over the weir. Its length was 102 feet and its width about 11.6 feet. A swinging apron gate was so arranged over the crest of the weir that, when opened, the water flowed freely into the measuring basin below, and when closed, with its upper edge against the weir, the overflow passed into a wooden diverting channel, placed across the top of the lock chamber, and flowed into Concord River. An electric sounder was attached to the gate framework, by which a signal was given when the edge of the swinging gate was at the center of the nappe, when either opening or closing. By this means the time of starting and stopping of each experimental period was observed on a marine chronometer. The depth on the weir was observed by hook gages. The readings were taken in wooden stilling boxes, 11 by 18 inches square, open at the top, and having a 1-inch round hole through the bottom, which was about 4 inches below the weir crest. The weir was in the lower quoin of the gate recess, and the hook gage boxes were in the upper quoin, projecting slightly beyond the main lock walls. In weirs with end

[a] Francis, J. B., Lowell Hydraulic Experiments, pp. 103–135. [b] Idem, pp. 96–102. [c] Idem, pp. 76–95.

contractions the full width of the channel was used. For suppressed weirs, a leading channel having a width equal to the length of the weir crest was formed by constructing vertical timber walls within the main canal, extending 20 feet upstream from the weir and having their upper ends flaring about 1 foot toward the canal walls. Water was freely admitted on both sides of these timber walls. The hook gage boxes were outside of this channel. The holes in the bottom were plugged, and flush piezometer pipes were used to connect the hook-gage boxes with the inner face of the side walls of the channel of approach. Observations of the head by hook gage were taken at intervals of about 15 seconds. Each experimental period covered from 190 to 900 seconds. The hook-gage readings were reduced to weir crest level as a datum and arranged in groups of two or three, which agreed closely. The mean head was determined by the correction formula (48). In one period, 18 observations of heads ranged from 0.6310 to 0.6605 foot; their arithmetical mean was 0.6428; the computed correction was minus 0.0008.

The measured head was corrected for velocity of approach by using the theoretical formula given below. The range and character of the experiments, together with the general results, are shown in the following table:

Thin-edged weir experiments of J. B. Francis at the lower locks, Lowell, Mass., 1852.

Serial numbers of experiments.		Total number.	Width of channel at upstream side of weir.	Depth of channel below top of weir at hook gage boxes.	Range of observed head, in feet.		Range of velocity of approach, in feet per second.		Length of weir crest in feet.	Number end contractions.	Approximate mean corrected head H, in feet.	Discharge coefficient C.		
From—	To—				From—	To—	From—	To—				Maximum.	Minimum.	Mean.
1	4	4	13.96	5.048	1.52430	1.56910	0.7682	0.7889	9.997	2	1.56	3.3318	3.3002	3.3181
5	10	6	13.96	5.048	1.23690	1.25490	.5901	.6000	9.997	2	1.25	3.3412	3.3159	3.3338
11	33	23	13.96	5.048	.91570	1.06920	.3951	.4863	9.997	2	1.00	3.3333	3.3110	3.3223
34	35	2	13.96	5.048	1.01025	1.02625	.3527	.3596	7.997	4	1.02	3.3617	3.3586	3.3601
36	43	8	13.96	2.014	1.02805	1.07945	.9496	1.0049	9.997	2	1.06	3.3567	3.3498	3.3527
44	50	7	9.992	5.048	.97450	.98675	.5376	.5455	9.995	0	0.98	3.3437	3.3366	3.3409
51	55	5	9.992	5.048	.99240	1.00600	.5477	.5589	9.995	0	1.00	3.3349	3.3243	3.3270
56	61	6	13.96	5.048	.77690	.81860	.3170	.3405	9.997	2	0.80	3.3287	3.3188	3.3246
62	66	5	13.96	2.014	.77115	.88865	.6694	.7963	9.997	2	0.83	3.3435	3.3376	3.3403
67	71	5	9.992	5.048	.7362	.81495	.3659	.4213	9.995	0	0.80	3.3424	3.3341	3.3393
72	78	7	13.96	5.048	.59190	.65525	.2182	.2509	9.997	2	0.62	3.3306	3.3237	3.3275
79	84	6	13.96	2.014	.63135	.65985	.5193	.5496	9.997	2	0.65	3.3278	3.3244	3.3262
85	88	4	13.96	2.014	.66940	.68815	.4382	.4526	7.997	4	0.68	3.3382	3.3333	3.3368

From a discussion of these experiments Francis presents the final formula—

$$\left.\begin{array}{l} Q=3.33LH^{\frac{3}{2}}. \\ \text{If there are end contractions,} \\ \qquad L=L'-0.1NH. \\ \text{If there is velocity of approach,} \\ \qquad H^{\frac{3}{2}}=\left[(D+h)^{\frac{3}{2}}-h^{\frac{3}{2}}\right]. \end{array}\right\} \quad . \quad . \quad (18)$$

The mean velocity v was determined by successive approximations; h was determined by the usual formula—

$$h=\frac{v^2}{2g}$$

The Francis formula for velocity of approach correction is cumbersome, and several substitutes have been devised, some of which are described in the following paragraphs.

(1) Determine the approximate velocity of approach v_1 by a single trial computation of Q, using $D=H$.
Then use

$$H=D+\frac{v_1}{2g}=D+h$$

to determine the final value of Q. For a given value of v this gives too large a value of H, but the approximate value of v_1 is somewhat too small, partially counterbalancing the error and usually giving a final value of Q sufficiently precise.

(2) By developing into series and omitting the powers h/D above the first, h being always relatively small, the following closely approximate equivalent of the Francis correction formula, given by Emerson,[a] is obtained:

$$H=D+h-\frac{2}{3}\sqrt{\frac{h^3}{D}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

(3) Hunking and Hart[b] derive from the Francis correction formula the following equivalent expression:

$$KD^{\frac{3}{2}}=H^{\frac{3}{2}}=(D+h)^{\frac{3}{2}}-h^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

$$K=\left[1+\frac{C^2}{2g}\left(\frac{D}{G}\right)^2K^2\right]^{\frac{3}{2}}-\left[\frac{C^2}{2g}\left(\frac{D}{G}\right)^2K^2\right]^{\frac{3}{2}} \quad . \quad . \quad (21)$$

where G is the area of channel section in which D is measured, per unit length of crest.

[a] Hydrodynamics, p. 286. [b] Jour. Franklin Inst., Phila., August, 1884, pp. 121-126.

For a suppressed weir,

$$G=P+D.$$

For a contracted weir,

$$G=\frac{A}{L-0.1ND.} \qquad \ldots\ldots\ldots \quad (22)$$

Hunking and Hart have computed values of K by the solution of the above formula for each 0.005 increment in D/G to 0.36. The results extended by formula (23) are given below.

Velocity of approach correction, factor K, Hunking and Hart formula, $H^{\frac{3}{2}}=KD^{\frac{3}{2}}$.

D/G	0.0	0.1	0.2	0.3	0.4	0.5	0.6
.000	1.00000	1.002628	1.009980	1.022359	1.039840	1.062250	1.08964
.005	1.000006	1.002785	1.010480	1.023110	1.040836	1.063495	1.091134
.010	1.000026	1.003053	1.010994	1.023875	1.041832	1.064740	1.092628
.015	1.000058	1.003335	1.011519	1.024653	1.042828	1.065985	1.094122
.020	1.000103	1.003628	1.012057	1.025444	1.043824	1.067230	1.095616
.025	1.000161	1.003933	1.012607	1.026248	1.045069	1.068724	1.097359
.030	1.000231	1.004251	1.013169	1.027065	1.046065	1.069969	1.098853
.035	1.000314	1.004581	1.013744	1.027895	1.047061	1.071214	1.100347
.040	1.000409	1.004923	1.014331	1.028739	1.048306	1.072708	1.102090
.045	1.000518	1.005278	1.014931	1.029596	1.049302	1.073953	1.103584
.050	1.000638	1.005644	1.015543	1.030467	1.050298	1.075198	1.105078
.055	1.000772	1.006023	1.016167	1.031350	1.051543	1.076692	1.106821
.060	1.000917	1.006414	1.016805	1.032248	1.052788	1.078186	1.108564
.065	1.001075	1.006817	1.017455	1.033117	1.053784	1.079431	1.110058
.070	1.001246	1.007232	1.018107	1.034113	1.055029	1.080925	1.111801
.075	1.001429	1.007659	1.018792	1.035109	1.056274	1.082419	1.113544
.080	1.001624	1.008099	1.019480	1.035856	1.057270	1.083664	1.115038
.085	1.001832	1.008551	1.020180	1.036852	1.058515	1.085158	1.116781
.090	1.002051	1.009015	1.020893	1.037848	1.059760	1.086652	1.118524
.095	1.002284	1.009491	1.021620	1.038844	1.061005	1.088146	1.120267

The general formula for K is too complex for common use. The expressions

$$K=1+0.2489\left(\frac{D}{G}\right)^2 \qquad \ldots\ldots\ldots \quad (23)$$

and

$$K=1+\left(\frac{D}{2G}\right)^2 \qquad \ldots\ldots\ldots \quad (24)$$

are stated to give results correct within one-hundredth and one-fiftieth of 1 per cent, respectively, for values of K less than 0.36.

EXPERIMENTS AND FORMULAS OF FTELEY AND STEARNS.

The first series of experiments by Fteley and Stearns on thin-edged weir discharge[a] were made in March and April, 1877, on a suppressed weir, with crest 5 feet in length, erected in Sudbury conduit below Farm Pond, Metropolitan waterworks of Boston.

Water from Farm Pond was let into the leading channel through

[a] Fteley, A., and Stearns, F. P., Experiments on the flow of water, etc.: Trans. Am. Soc. C. E., vol. 12, Jan., Feb., Mar., 1883, pp. 1-118.

ead-gates until the desired level for the experiment, as found by revious trial, was reached. A swinging gate was then raised from ıe crest of the weir and the water was allowed to flow over. The ıaintenance of a uniform regimen was facilitated by the large area nd the consequent small variation of level in Farm Pond, so that the utflow from the gates was sensibly proportional to the height they ere raised. The water flowed from the weir into the conduit chan-el below, and was measured volumetrically. For the smaller heads ıe length of the measuring basin was 22 feet, and for the larger eads 367 feet.

The crest depth was observed by hook gage in a pail below the weir, ›nnected to the channel of approach by a rubber tube entering the ›p of the side wall, 6 feet upstream from the weir crest. Hook-gage eadings of head were taken every half minute until uniform regimen as established, and every minute thereafter. The depths in the meas-ring basin were also taken by hook gage. The bottom of the conduit as concave, and was graded to a slope of 1 foot per mile. It was ›vered with water previous to each experiment, leaving a nearly ectangular section.

The experiments in 1877 included 31 depths on a suppressed weir f 5 feet crest length, 3.17 feet high. The observed heads varied rom 0.0735 to 0.8198 foot.

In 1879 a suppressed weir, with a crest length of 19 feet, was rected in Farm Pond Gate House. Head-gates and screens were lose to weir; otherwise the apparatus for measuring head and starting nd stopping flow was similar to that used in previous experiments. 'he crest of the weir was an iron bar 3½ inches wide and one-fourth ıch thick, planed and filed and attached to the upper weir timber with crews. No variation in level of the weir crest occurred. As in the ›receding experiments, no by-pass was provided, and the entire over-low entered Sudbury conduit below the weir. The conduit was artly filled with water at the start, leaving a nearly rectangular sec-ion, 11,300 feet in length and about 9 feet wide. A difference of 3 eet in water level was utilized in measuring discharge, the total capac-ty being 300,272 cubic feet. Semipartitions were provided to reduce ›scillation of the water. Many observations, covering a considerable ›eriod of time, were required to determine the true water level. This eries of experiments included 10 depths on a suppressed weir 19 feet. ong and 6.55 feet high, with measured heads varying from 0.4685 to .6038 feet and velocities of approach ranging from 0.151 to 0.840 foot ›er second.

From measurements on weirs 5 and 19 feet in length, respectively, nd from a recalculation of the experiments of James B. Francis, 'teley and Stearns obtained the final formula

$$Q=3.31LH^{\frac{3}{2}}+0.007L \quad . \quad . \quad . \quad . \quad . \quad . \quad (9$$

In the above, if there is velocity of approach,

$H=D+\alpha h.$

$\alpha=1.5$ for suppressed weirs.

$\alpha=2.05$ for weirs with end contractions.

The value of the velocity head coefficient α was determined from 94 additional experiments on the 5-foot weir in 1878. These involved measured heads ranging from 0.1884 to 0.9443 foot, heights of weir ranging from 0.50 to 3.47 feet, and velocities of approach reaching a maximum of 2.35 feet per second. Also 17 experiments were made on weirs 3, 3.3, and 4 feet long respectively; the first with two and the last two with one end contraction. These experiments included measured heads varying from 0.5574 to 0.8702 foot, and velocities of approach from 0.23 to 1.239 feet per second.

In all experiments on velocity of approach, the head was measured 6 feet upstream from crest. The width of channel was 5 feet.[a]

Fteley and Stearns found the following values of α for suppressed weirs:

Fteley and Stearns's value of α for suppressed weirs.

Measured depth on weir, in feet.	Depth of channel of approach below weir crest, in feet.			
	0.50	1.00	1.70	2.60 [b]
0.2	1.70	1.87	1.66	1.51
.3	1.53	1.83	1.65	1.50
.4	1.53	1.79	1.63	1.49
.5	1.53	1.75	1.62	1.48
.6	1.52	1.71	1.60	1.47
.7	1.51	1.68	1.59	1.46
.8	[c] 1.50	[c] 1.65	1.57	1.45
.9	1.49	1.63	1.56	[c] 1.44
1.0	1.48	1.61	1.54	1.43
1.1	.....	1.59	1.53	1.42
1.2	.....	1.57	1.51	1.41
1.3	.....	1.55	1.49	1.40
1.4	.....	1.54	1.48	1.39
1.5	.....	1.52	1.46	1.38
1.6	.....	1.51	1.44	1.37
1.7	.....	1.49	1.43	1.36
1.8	.....	.....	1.41	1.35
1.9	.....	.....	1.40	1.34
2.0	.....	.....	1.38	1.33

[a] Fteley and Stearns, idem pp. 5-23.

[b] Applicable to greater heights of weir.

[c] Limit of experiments.

Current-meter measurements showed a nearly uniform distribution velocities in the channel of approach above the 19-foot weir, a fact be taken account of when the formulas are applied to cases where e velocity of approach varies in different portions of the leading annel.

If there are end contractions, the net length of weir should be deterined by the Francis formula,

$$L=L'-0.1NH.$$

The head should be measured at the surface of the channel of proach, 6 feet upstream from the weir crest.

BAZIN'S EXPERIMENTS.

Bazin's experiments on thin-edged weirs were performed in the side annel of the Canal de Bourgogne, near Dijon, France, and were gun in 1886. Their results were published in Annales des Ponts et haussées and have been translated by Marichal and Trautwine.[a]

The standard weir consisted of horizontal timbers 4 inches square, ith an iron crest plate 0.276 inch in thickness. Air chambers were aced at the ends of the weir on the downstream side, to insure full ration of the nappe. End contractions were suppressed. The ight of the first weir was 3.27 feet above channel bottom, and the ad was measured in "Bazin pits," one at each side of the channel .40 feet upstream from the weir crest. The pit consisted of a latal chamber in the cement masonry forming the walls of the canal. e chamber was square, 1.64 feet on each side, and communicated ith the channel of approach by a circular opening 4 inches in diameter, aced at the bottom of the side wall and having its mouth exactly ish with the face of the wall. The oscillations of the water surface the lateral chamber were thus rendered much less prominent than the channel of approach. The water level in the Bazin pit was served by dial indicators attached to floats, the index magnifying e variations in water level four times, the datum for the indicators ving been previously determined by means of hook gages placed ove the crest of the weir and by needle-pointed slide gages in the ading channel.

A drop gate was constructed on the crest of the weir to shut off the scharge at will. In each experiment the head-gates through which e water entered the leading channel were first raised and the water as allowed to assume the desired level. The weir gate was then ised, and the head-gates were manipulated to maintain a nearly con-

[a] Bazin, H., Recent experiments on flow of water over weirs, translated from the French by Marichal and Trautwine: Proc. Engineers' Club Phila., vol. 7, Jan., 1890, pp. 259–310; vol. 9, pp. 231–244, 7–319; vol. 10, pp. 121–164.

stant inflow. The arithmetical mean of the observations during each period of uniform regimen was used as the measured head for that experiment.

The overflow passed into a measuring channel, 656.17 feet in length, whose walls were made of smooth Portland cement concrete. The channel was 6.56 feet wide, its side walls were 3.937 feet high, and its lower end was closed by water-tight masonry. Its bottom was graded to a slope of about 1:1,000. The volume of inflow was determined by first covering the channel bottom with water, then noting the change of level during each experimental period, the capacity of the channel at various heights having previously been carefully determined. A slight filtration occurred, necessitating a correction of about one-eighth of 1 per cent of the total volume. The observations for each regimen were continued through a period of 12 to 30 minutes.

Sixty-seven experiments were made on a weir 3.72 feet high, including heads from the least up to 1.017 feet. Above this point the volumetric measuring channel filled so quickly as to require the use of a shorter weir. Thirty-eight experiments were made with a standard weir, 3.28 feet long and 3.72 feet high, with heads varying from the least up to 1.34 feet. For heads exceeding 1.34 feet it was necessary to reduce the height of the weir in order that the depth above the weir should not exceed that of the channel of approach. Forty-eight experiments were made on a weir 1.64 feet long and 3.297 feet high, with heads ranging from the least up to 1.780 feet. These experiments sufficed to calibrate the standard weir with a degree of accuracy stated by Bazin as less than 1 per cent of error.

In order to determine the effect of varying velocities of approach the following additional series of experiments were made on suppressed weirs 2 meters (6.56 feet) in length.

Experiments on suppressed weirs 2 meters in length.

Number of experiments.	Range of head in feet.		Height of experimental weir, in feet.
	From—	To—	
28+30	0.489	1.443	2.46
29+29	.314	1.407	1.64
27+41	.298	1.338	1.15
44	.296	1.338	0.79

The standard weir was 3.72 feet high, and the experimental weirs were placed 46 to 199 meters downstream. The discharge was not measured volumetrically. A uniform regimen of flow was established and the depths on the two weirs were simultaneously observed during each period of flow.

These experiments afforded data for the determination of the relative effect of different velocities of approach, corresponding to the different depths of the leading channel.

From these experiments Bazin deduces coefficients for a thin-edged weir 3.72 feet high, for heads up to 1.97 feet, stated to give the true discharge within 1 per cent.[a]

BAZIN'S FORMULAS FOR THIN-EDGED WEIRS.

Starting with the theoretical formula for a weir without velocity of approach, in the form

$$Q=\mu LH\sqrt{2gH}$$

and substituting

$$D+\alpha\frac{v^2}{2g}$$

for H, in the case of a weir having velocity of approach, there results,

$$Q=\mu L\left(D+\alpha\frac{v^2}{2g}\right)\sqrt{2g\left(D+\alpha\frac{v^2}{2g}\right)}.$$

Bazin obtained, by mathematical transformation, the equivalent[b]

$$Q=\mu LD\sqrt{2gD}\left(1+\alpha\frac{v^2}{2gD}\right)^{\frac{3}{2}},$$

or

$$Q=\mu\left(1+\alpha\frac{v^2}{2gD}\right)^{\frac{3}{2}}LD\sqrt{2gD}.$$

Bazin writes

$$m=\mu\left(1+\alpha\frac{v^2}{2gD}\right)^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

for which equation he obtains, by mathematical transformation, the approximate equivalent[c]

$$m=\mu\left(1+\frac{3}{2}\alpha\frac{v^2}{2gD}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

The calculation of the factor v appearing in this formula requires the discharge Q to be known.

Assuming that the channel of approach has a constant depth P below the crest of the weir, and that its width is equal to the length of the

[a] Bazin, H., Expériences nouvelles sur l'écoulement en déversoir: Ann. Ponts et Chaussées, Mém. et Doc., 1898, 2me trimestre. See translation by Marichal and Trautwine in Proc. Eng. Club Phila., vol. 7, pp. 259–310; vol. 9, pp. 231–244.

[b] The steps in the derivation of this formula are given by Trautwine and Marichal in their translation of Bazin's report of his experiments, in Proc. Eng. Club Phila., vol. 7, p. 280.

[c] The steps in detail are given by Trautwine and Marichal in their translation of Bazin, in Proc. Eng. Club Phila., vol. 7, No. 5, p. 281.

weir, v may be expressed in terms of these factors, and of the discharge ($Q=mLD\sqrt{2gD}$).

$$v=\frac{Q}{L(P+D)}.$$

Using this value of v, Bazin obtains the expression

$$m=\mu\left[1+\omega\left(\frac{D}{D+P}\right)^2\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

where $\omega=\frac{3}{2}\alpha m^2$. ω is a nearly constant factor, varying only with m^2. The value of ω as well as that of α can be determined by comparative experiments on thin-edged weirs of different heights.[a]

From a discussion of his own experiments and those of Fteley and Stearns, Bazin finally obtained the formulas

$$\left.\begin{array}{l} Q=\mu LH\sqrt{2gH}, \text{ no velocity of approach;} \\ Q=mLD\sqrt{2gD}, \text{ with velocity of approach.} \end{array}\right\} \quad . \quad . \quad (29)$$

$$\mu=0.405+\frac{0.003\times 3.281}{D}=0.405+\frac{0.00984}{D}{}^{b} \quad . \quad . \quad . \quad (30)$$

For a weir with velocity of approach $\alpha=\frac{5}{3}$ and $\omega=0.55$. Substituting in equations (27) and (28),

$$m=\mu\left(1+\frac{3}{2}\cdot\frac{5}{3}\cdot\frac{v^2}{2gD}\right)=\mu\left(1+2.5\frac{v^2}{2gD}\right) \quad . \quad . \quad . \quad (31)$$

$$m=\mu\left[1+0.55\left(\frac{D}{P+D}\right)^2\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (32)$$

These formulas give values of m agreeing with the results of the experiments within 1 per cent for weirs exceeding about 1 foot in height within the experimental range of head.

Approximately, for heads from 4 inches to 1 foot,

$$m=0.425+0.21\left(\frac{D}{P+D}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

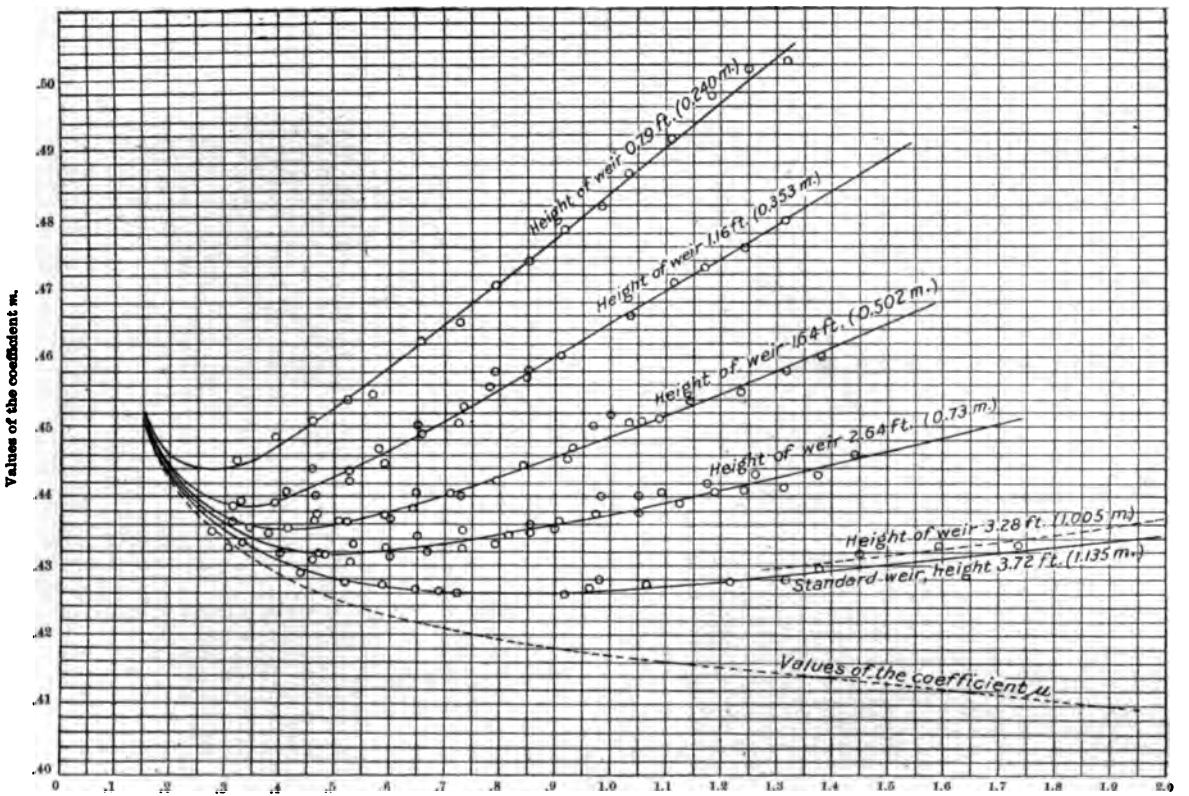
correct within 2 to 3 per cent.

The following table gives Bazin's experimental coefficients, the head and height of weir (originally meters) having been reduced to feet:

---

[a] For detailed analysis see Trautwine and Marichal, Proc. Eng. Club Phila., vol. 7, pp. 282-283.

[b] Experimental tabular values of μ differing very slightly from the formula within the range of Bazin's experiments are also given.



BAZIN'S EXPERIMENTAL COEFFICIENT *m* FOR THIN-EDGED WEIRS OF VARYING HEIGHT FOR USE IN THE FORMULA $Q = mLD\sqrt{2gD}$.

Values of the Bazin coefficient C in the formula $Q=CLH^{\frac{3}{2}}$ for a thin-edged weir, without end contraction.

Measured head *D*.	Height of crest of weir above bed of channel of approach, in feet.										Measured head *D*.
	0.66	0.98	1.31	1.64	1.97	2.62	3.28	4.92	6.56	∞	
Feet.	*C*	*C*	*C*	*C*	*C*	*C*	*C*	*C*	*C*	*C*	Meters.
0.164	3.673	3.633	3.617	3.609	3.601	3.601	3.601	3.593	3.593	3.594	0.05
.197	3.657	3.609	3.585	3.569	3.569	3.561	3.553	3.553	3.553	3.550	.06
.230	3.649	3.593	3.569	3.553	3.545	3.537	3.529	3.529	3.521	3.522	.07
.262	3.657	3.585	3.553	3.537	3.529	3.513	3.513	3.505	3.505	3.499	.08
.295	3.665	3.585	3.545	3.529	3.513	3.497	3.497	3.489	3.481	3.481	.09
.328	3.681	3.585	3.545	3.521	3.505	3.489	3.481	3.473	3.473	3.466	.10
.394	3.705	3.593	3.545	3.513	3.497	3.473	3.465	3.449	3.449	3.441	.12
.459	3.737	3.609	3.553	3.513	3.489	3.465	3.449	3.432	3.432	3.422	.14
.525	3.777	3.633	3.561	3.513	3.489	3.457	3.440	3.424	3.416	3.405	.16
.591	3.810	3.657	3.569	3.521	3.489	3.457	3.432	3.416	3.408	3.392	.18
.656	3.850	3.681	3.585	3.529	3.497	3.457	3.432	3.408	3.392	3.380	.20
.722	3.882	3.705	3.601	3.545	3.505	3.457	3.432	3.400	3.392	3.371	.22
.787	3.914	3.729	3.625	3.561	3.513	3.465	3.432	3.400	3.384	3.364	.24
.853	3.946	3.753	3.649	3.577	3.529	3.465	3.440	3.400	3.384	3.358	.26
.919	3.978	3.785	3.665	3.593	3.537	3.473	3.440	3.400	3.384	3.353	.28
.984	4.010	3.810	3.689	3.609	3.553	3.481	3.449	3.400	3.376	3.348	.30
1.050	.....	3.834	3.705	3.625	3.561	3.497	3.449	3.400	3.376	3.343	.32
1.116	.....	3.858	3.721	3.641	3.577	3.505	3.457	3.400	3.376	3.338	.34
1.181	.....	3.874	3.745	3.657	3.593	3.513	3.465	3.400	3.376	3.333	.36
1.247	.....	3.898	3.761	3.673	3.601	3.521	3.465	3.400	3.376	3.328	.38
1.312	.....	3.922	3.785	3.681	3.617	3.529	3.473	3.400	3.376	3.323	.40
1.378	.....	3.938	3.801	3.697	3.625	3.537	3.481	3.408	3.376	3.319	.42
1.444	.....	3.962	3.818	3.713	3.641	3.545	3.489	3.408	3.376	3.316	.44
1.509	.....	3.978	3.834	3.729	3.657	3.553	3.489	3.408	3.376	3.311	.46
1.575	.....	.....	3.850	3.745	3.665	3.561	3.497	3.408	3.376	3.306	.48
1.640	.....	.....	3.866	3.753	3.681	3.569	3.505	3.416	3.376	3.303	.50
1.706	.....	.....	3.874	3.769	3.689	3.577	3.513	3.416	3.376	3.298	.52
1.772	.....	.....	3.890	3.785	3.697	3.585	3.513	3.416	3.376	3.294	.54
1.837	.....	.....	3.906	3.793	3.713	3.593	3.521	3.424	3.376	3.289	.56
1.903	.....	.....	3.922	3.810	3.721	3.601	3.529	3.424	3.376	3.285	.58
1.969	.....	.....	3.930	3.818	3.737	3.617	3.537	3.424	3.376	3.282	.60
Meters.	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	∞	.....

This table, unfortunately, is inconvenient for interpolation in English units. The values also differ slightly from those computed from the formulas. The table illustrates the difficulty of practical application of a weir formula in which the coefficient varies rapidly both with head and height of weir.

A table has been added giving values of μ computed by formula (30) for a thin-edged weir without velocity of approach.

Values of μ in the Bazin formula for weirs of infinite height, with no velocity of approach.

H. *Feet.*	0.	0.01.	0.02.	0.03.	0.04.	0.05.	0.06.	0.07.	0.08.	0.09.	0.1.
0.0	.....	1.389	0.8970	0.7331	0.6510	0.6018	0.5693	0.5457	0.5280	0.5142	0.5034
.1	0.5034	.4944	.4870	.4807	.4753	.4706	.4665	.4628	.4596	.4568	.4542
.2	.4542	.4518	.4497	.4478	.4460	.4444	.4429	.4414	.4401	.4389	.4378
.3	.4378	.4367	.4357	.4348	.4339	.4331	.4324	.4316	.4309	.4302	.4296
.4	.4296	.4290	.4284	.4278	.4273	.4268	.4264	.4260	.4255	.4251	.4247
.5	.4247	.4243	.4239	.4236	.4232	.4229	.4225	.4222	.4219	.4216	.4214
.6	.4214	.4211	.4208	.4206	.4204	.4202	.4200	.4197	.4195	.4193	.4191
.7	.4191	.4189	.4187	.4185	.4183	.4181	.4180	.4178	.4176	.4174	.4173
.8	.4173	.4171	.4170	.4168	.4167	.4166	.4164	.4163	.4162	.4160	.4159
.9	.4159	.4158	.4157	.4156	.4154	.4153	.4152	.4151	.4150	.4149	.4148
1.0	.4148	.4147	.4146	.4146	.4145	.4144	.4143	.4142	.4141	.4140	.4139
1.1	.4139	.4139	.4138	.4137	.4136	.4136	.4135	.4134	.4133	.4133	.4132
1.2	.4132	.4131	.4131	.4130	.4129	.4129	.4128	.4127	.4127	.4126	.4126
1.3	.4126	.4125	.4124	.4124	.4123	.4123	.4122	.4122	.4121	.4121	.4120
1.4	.4120	.4120	.4119	.4119	.4118	.4118	.4117	.4117	.4116	.4116	.4116
1.5	.4116	.4115	.4115	.4114	.4114	.4113	.4113	.4113	.4112	.4112	.4112
1.6	.4112	.4111	.4111	.4110	.4110	.4110	.4109	.4109	.4108	.4108	.4108
1.7	.4108	.4108	.4107	.4107	.4107	.4106	.4106	.4106	.4105	.4105	.4105
1.8	.4105	.4104	.4104	.4104	.4103	.4103	.4103	.4103	.4102	.4102	.4102
1.9	.4102	.4102	.4101	.4101	.4101	.4100	.4100	.4100	.4100	.4099	.4099
2.0	.4099	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

DERIVED FORMULAS FOR THIN-EDGED RECTANGULAR WEIRS.

A number of weir formulas have been derived from subsequent analysis or recomputation of the experiments of Francis, Fteley and Stearns, and Bazin, differing more or less from those given by the experimenters.

FTELEY AND STEARNS-FRANCIS FORMULA.[a]

$$Q=3.33LH^{\frac{3}{2}}+0.007L \quad . \quad . \quad . \quad . \quad . \quad (34)$$

Correction for end contractions is to be made by the Francis formula; velocity of approach correction by the Fteley and Stearns formulas

$$H=D+1.5h, \qquad \text{for suppressed weir.}$$
$$H=D+2.05h, \qquad \text{for contracted weir.}$$

HAMILTON SMITH'S FORMULA.[b]

The base formula adopted is

$$Q=\frac{2}{3}\,MLH\sqrt{2gH} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

[a] Fteley and Stearns, Experiments on the flow of water, etc.: Trans. Am. Soc. C. E., vol. 12, p. 82.
[b] Smith, Hamilton, Hydraulics, pp. 128-132.

he velocity of approach correction is made by the use of the nulas

$$H=D+1.4h, \quad \text{for contracted weirs.}^a$$
$$H=D+1\tfrac{1}{3}h, \quad \text{for suppressed weirs.}$$

diagram and tables of values of the coefficient M are given by the ıor. The correction for partial or complete contraction is included ıe coefficient, separate values of M being given for suppressed and ;racted weirs.

laking $C=\frac{2}{3}M\sqrt{2g}$, the Smith formula (35) may be written

$$Q=CLH^{\frac{3}{2}},$$

ch is directly comparable with the Francis formula.
nith's coefficients in the above form are given in the following es.

ilton Smith's coefficients for weirs with contraction suppressed at both ends, for use in the formula $Q=CLH^{\frac{3}{2}}$.

H= Head, in feet.	L'=length of weir, in feet.								
	19	15	10	7	5	4	3[a]	2[a]	0.66[b]
0.1	3.515	3.515	3.520	3.520	3.526	.....	.....	.....	3.611
.15	3.440	3.445	3.445	3.451	3.451	3.461	3.472	3.488	3.542
.2	3.397	3.403	3.408	3.408	3.413	3.429	3.435	3.450	3.510
.25	3.371	3.376	3.381	3.386	3.392	3.403	3.413	3.429	3.494
.3	3.349	3.354	3.360	3.365	3.376	3.386	3.403	3.418	3.483
.4	3.322	3.328	3.333	3.344	3.360	3.371	3.386	3.403	3.478
.5	3.312	3.317	3.322	3.338	3.354	3.371	3.386	3.408	3.478
.6	3.306	3.312	3.317	3.333	3.354	3.371	3.392	3.413	3.483
.7	3.306	3.312	3.317	3.338	3.360	3.376	3.397	3.424	3.494
.8	3.306	3.317	3.322	3.344	3.365	3.386	3.408	3.441	3.510
.9	3.312	3.317	3.328	3.354	3.375	3.397	3.418	3.451	.....
1.0	3.312	3.322	3.338	3.360	3.386	3.408	3.429	3.467	.....
1.1	3.317	3.328	3.344	3.371	3.397	3.419	3.445	.....	.....
1.2	3.317	3.333	3.349	3.381	3.403	3.429	3.456	.....	.....
1.3	3.322	3.338	3.360	3.386	3.413	3.440	3.467	.....	.....
1.4	3.328	3.344	3.365	3.392	3.424	3.445	.....	.....	.....
1.5	3.328	3.344	3.371	3.403	3.429	3.456	.....	.....	.....
1.6	3.333	3.349	3.376	3.408	3.435	3.461	.....	.....	.....
1.7	3.333	3.349	3.381	3.413	.....	.....	.....	.....	.....
2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....

[a] The use of the head corresponding to central surface velocity without correction, to determine D, is not recommended.
[b] Approximate.

Hamilton Smith's coefficients for weirs with two complete end contractions, for use in the formula $Q=CLH^{\frac{3}{2}}$.

H= Head.	L'=length of weir, in feet.										
	0.66	1 *a*	2	2.6	3	4	5	7	10	15	19
0.1	3.381	3.419	3.456	3.478	3.488	3.494	3.494	3.499	3.504	3.504	3.510
.15	3.312	3.344	3.392	3.408	3.413	3.419	3.424	3.424	3.429	3.435	3.435
.2	3.269	3.306	3.349	3.365	3.371	3.376	3.376	3.381	3.386	3.392	3.392
.25	3.237	3.274	3.322	3.333	3.338	3.344	3.349	3.354	3.360	3.360	3.365
.3	3.215	3.253	3.296	3.306	3.312	3.322	3.322	3.333	3.338	3.338	3.344
.4	3.183	3.215	3.258	3.274	3.280	3.285	3.290	3.301	3.306	3.312	3.317
.5	3.156	3.189	3.237	3.247	3.253	3.264	3.269	3.280	3.290	3.295	3.301
.6	3.140	3.172	3.215	3.231	3.237	3.247	3.253	3.269	3.280	3.285	3.290
.7	3.130	3.156	3.199	3.210	3.226	3.231	3.242	3.258	3.274	3.280	3.285
.8	.....	.....	3.183	3.199	3.215	3.221	3.231	3.247	3.269	3.274	3.280
.9	.....	.....	3.167	3.189	3.199	3.210	3.226	3.242	3.258	3.269	3.274
1.0	.....	.....	3.156	3.172	3.183	3.199	3.215	3.231	3.253	3.264	3.269
1.1	.....	.....	3.140	3.162	3.172	3.189	3.205	3.226	3.242	3.258	3.264
1.2	.....	.....	3.130	3.151	3.162	3.178	3.194	3.215	3.237	3.253	3.264
1.3	.....	.....	3.114	3.135	3.151	3.167	3.199	3.205	3.231	3.247	3.258
1.4	.....	.....	3.108	3.124	3.140	3.156	3.178	3.199	3.221	3.242	3.258
1.5	.....	.....	.....	3.114	3.130	3.151	3.167	3.189	3.215	3.237	3.253
1.6	.....	.....	.....	3.103	3.114	3.140	3.162	3.183	3.210	3.231	3.247
1.7	.....	.....	.....	.....	.....	.....	.....	3.178	3.205	3.226	3.247
2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

a Approximate.

Hamilton Smith's coefficient C for long weirs.

H	0.1	0.2	0.3	0.4	0.5	0.6	0.7
0.00	3.5096	3.3972	3.3438	3.3170	3.3010	3.2956	3.2849
.01	3.4957	3.3908	3.3411	3.3154	3.3005	3.2945	3.2838
.02	3.4818	3.3844	3.3384	3.3138	3.2999	3.2935	3.2828
.03	3.4678	3.3780	3.3358	3.3122	3.2994	3.2924	3.2817
.04	3.4539	3.3716	3.3331	3.3106	3.2988	3.2913	3.2806
.05	3.4400	3.3652	3.3304	3.3090	3.2983	3.2902	3.2796
.06	3.4314	3.3537	3.3277	3.3074	3.2978	3.2892	3.2785
.07	3.4229	3.3512	3.3250	3.3058	3.2972	3.2881	3.2773
.08	3.4143	3.3488	3.3224	3.3042	3.2967	3.2870	3.2762
.09	3.4058	3.3463	3.3197	3.3026	3.2961	3.2860	3.2752

Hamilton Smith's formula is based on a critical discussion of tl experiments of Lesbros, Poncelet and Lesbros, James B. Franci Fteley and Stearns, and Hamilton Smith; including series with ar without contractions and having crest lengths from 0.66 to 19 feet.

SMITH-FRANCIS FORMULA.

The Smith-Francis formula,[a] based on Francis's experiments, reduced the basis of correction for contractions and velocity of approach ed with Hamilton Smith's formula, is,

r a suppressed weir,

$$Q=3.29\left(L+\frac{H}{7}\right)H^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (36)$$

r weir of great length or with one contraction,

$$Q=3.29LH^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (37)$$

r weir with full contraction,

$$Q=3.29\left(L-\frac{H}{10}\right)H^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (38)$$

If there is velocity of approach,

$H=D+1.4\ h$, for a contracted weir.
$H=D+1\frac{1}{3}\ h$, for a suppressed weir.

PARMLEY'S FORMULA.[b]

Parmley's formula is

$$Q=CKLD^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (39)$$

If there are end contractions, the correction is to be made by the ancis formula,

$$L=L'-0.1NH$$

The factor K represents the correction for velocity of approach. The factor has been derived by comparing the velocity correction ctor in the Bazin formula (formula 32), written in the form

$$K=\left[1+0.55\left(\frac{a}{A}\right)^2\right],$$

ith the approximate Francis correction as deduced by Hunking and art (formula 23), written in the form

$$K=\left[1+0.2489\left(\frac{a}{A}\right)^2\right],$$

here a is the area of the section of discharge, for either a suppressed r contracted weir, and A is the section of the leading channel. It is bserved that there is an approximately constant relation between the wo corrections, that of Bazin being 2.2 times that of Francis.

[a] Smith, Hamilton, Hydraulics, pp. 99 and 137.
[b] Rafter, G. W., On the flow of water over dams: Trans. Am. Soc. C. E., vol. 44, pp. 350–359, discussion by *Walter C. Parmley*.

Parmley adopts the Bazin correction and gives the following tabl which may also conveniently be applied in computing discharge b Bazin's formula.

The discharge coefficient C used by Parmley is that for a weir wit no velocity of approach, as in the Francis formula. It is not, how ever, constant. Its values have been deduced from a mean curve rep resenting the experiments of Francis, Fteley and Stearns, and Bazin.

Velocity of approach correction, K, Parmley and Bazin formulas.

$\frac{a}{A}$	0	0.1	0.2	0.3	0.4	0.5
0.00	.....	1.0055	1.0220	1.0495	1.0880	1.1375
.01	1.0001	1.0066	1.0243	1.0529	1.0925	1.1431
.02	1.0002	1.0079	1.0266	1.0563	1.0970	1.1487
.03	1.0005	1.0093	1.0291	1.0599	1.1017	1.1545
.04	1.0009	1.0108	1.0317	1.0636	1.1065	1.1604
.05	1.0014	1.0124	1.0344	1.0674	1.1114	1.1664
.06	1.0020	1.0141	1.0372	1.0713	1.1164	1.1725
.07	1.0027	1.0159	1.0401	1.0753	1.1215	1.1787
.08	1.0035	1.0178	1.0431	1.0794	1.1267	1.1850
.09	1.0044	1.0198	1.0463	1.0837	1.1321	1.1915

Parmley's weir formula, coefficient C.

D, feet.	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.1	3.580	3.568	3.556	3.544	3.532	3.520	3.512	3.503	3.495	3.486
.2	3.478	3.471	3.464	3.458	3.451	3.444	3.439	3.434	3.430	3.425
.3	3.420	3.416	3.412	3.408	3.404	3.400	3.397	3.394	3.391	3.388
.4	3.385	3.383	3.381	3.380	3.378	3.376	3.374	3.373	3.371	3.370
.5	3.368	3.367	3.366	3.364	3.363	3.362	3.361	3.360	3.360	3.359
.6	3.358	3.357	3.356	3.356	3.355	3.354	3.353	3.353	3.352	3.352
.7	3.351	3.351	3.350	3.350	3.349	3.349	3.348	3.348	3.347	3.347
.8	3.346	3.345	3.345	3.344	3.344	3.343	3.342	3.342	3.341	3.341
.9	3.340	3.339	3.339	3.338	3.338	3.337	3.336	3.336	3.335	3.335
1.0	3.334	3.334	3.333	3.332	3.332	3.332	3.331	3.330	3.330	3.329
1.1	3.329	3.328	3.328	3.328	3.327	3.326	3.326	3.326	3.325	3.324
1.2	3.324	3.324	3.323	3.322	3.322	3.322	3.321	3.320	3.320	3.320
1.3	3.319	3.318	3.318	3.317	3.317	3.316	3.315	3.315	3.314	3.314
1.4	3.313	3.312	3.312	3.311	3.311	3.310	3.309	3.309	3.308	3.308
1.5	3.307	3.306	3.306	3.305	3.305	3.304	3.303	3.303	3.302	3.302
1.6	3.301	3.301	3.300	3.300	3.299	3.298	3.298	3.298	3.297	3.296
1.7	3.296	3.295	3.295	3.294	3.294	3.293	3.292	3.292	3.291	3.291
1.8	3.290	3.290	3.289	3.288	3.288	3.288	3.287	3.286	3.286	3.285
1.9	3.285	3.285	3.284	3.284	3.283	3.282	3.282	3.282	3.281	3.280
2.0	3.280	.....	.....	.....	.....	.....	.....	.....	.....	.....

EXTENSION OF THE WEIR FORMULA TO HIGHER HEADS.

It will be noticed that all the accepted formulas for discharge over thin-edged rectangular weirs are based on experiments in which the head did not exceed 2 feet above crest. It is often desirable to utilize the weir for stream gagings where the head is greater, especially for the determination of maximum discharge of streams, the head frequently being as large as 6, 8, or even 10 or 12 feet.

In the experiments at Cornell University on weirs of irregular section it was often necessary to utilize depths on the standard weir exceeding the known limit of the formula. A series of experiments was accordingly carried out in which a depth on a standard thin-edged weir (16 feet long) not exceeding the limit of the formula was utilized to determine the discharge over a similar but shorter standard thin-edged weir (6.56 feet long) for depths up to approximately 5 feet.[a] The results of these experiments, as recomputed, eliminating slight errors in the original, are given below.

It will be noted that the weir was short and the velocity of approach relatively large, yet, according to the results when corrected by the Francis method, the average value of C' for heads from 0.75 to 4.85 feet is 3.296, or 98.88 per cent of the Francis coefficient for a thin-edged weir. The average value of C' for heads from 0.746 foot to 2 feet is 3.266, and for heads from 2 to 4.85 feet, 3.278.

United States Deep Waterways experiments at Cornell hydraulic laboratory for extension of thin-edged weir formula.

Standard weir, 16 feet long, 13.13 feet high.		Lower thin-edged weir: $P=5.2$, $L=6.56$.					Q, cubic feet per second, per foot (corrected).	$C'=\frac{Q}{H^{\frac{3}{2}}}$
Cor. D, longitudinal, piezometer, centimeters.	Q, Bazin formula, in cubic feet per second.	Observed P, flush, piezometer, centimeters.	D, in feet.	$\frac{D}{P+D}$	K Hunking and Hart.	$H^{\frac{3}{2}}$		
1	2	3	4	5	6	7	8	9
12.28	14.12	22.744	0.7462	0.1255	1.0041	0.6469	2.1066	3.256
15.30	19.42	27.855	.9139	.1495	1.0056	.8787	2.9143	3.317
18.39	25.35	33.175	1.0885	.1731	1.0075	1.1434	3.8183	3.331
21.65	32.24	39.419	1.2933	.1992	1.0099	1.4849	4.8685	3.279
24.16	37.86	44.000	1.4436	.2173	1.0122	1.7564	5.7252	3.260
27.21	45.13	49.699	1.6306	.2387	1.0141	2.1116	6.8333	3.236
30.16	52.62	55.213	1.8115	.2583	1.0166	2.4787	7.9750	3.218
30.22	52.77	55.128	1.8088	.2581	1.0166	2.4730	7.9977	3.234
37.90	73.46	68.238	2.2389	.3010	1.0225	3.4254	11.1516	3.226
44.22	92.79	80.566	2.6434	.3370	1.0283	4.4193	14.0960	3.190
59.00	143.90	105.639	3.4660	.4000	1.0398	6.6095	21.8902	3.312
74.22	202.37	130.286	4.2747	.4512	1.0504	9.2867	30.8008	3.317
81.69	233.81	142.557	4.6773	.4735	1.0557	10.6789	35.5933	3.333

[a] Rafter, G. W., On the flow of water over dams: Trans. Am. Soc. C. E., vol. 44, p. 397.

If it is borne in mind that the influences which go to make up variation in the weir coefficient are more potent for low than for larger heads, it may be confidently asserted that the Francis formula is applicable within 2 per cent for heads as great as 5 feet, and by inference it is probably applicable for much greater heads as well.

COMPARISON OF WEIR FORMULAS.

The later weir formulas all give results agreeing, for the range of heads covered, within the limit of accuracy of ordinary stream measurements. Which of the several formulas to use will be determined by convenience and by the conditions attending the measurements.

The Francis formula is applicable for weirs with perfect bottom contraction and for any head above 0.50 foot.

The Hamilton Smith, Fteley and Stearns, and Bazin formulas are more accurate for very slight heads, or where bottom contraction is imperfect, this element, which tends to increase discharge, being included in the larger velocity of approach correction. These formulas are, however, based on experiments none of which exceeded 2 feet head, and they have not been extended.

For suppressed weirs in rectangular channels having conditions closely duplicating Bazin's experiments, his formula is probably most applicable. The head should preferably be measured in a Bazin pit, opening at the bottom of the channel, 16.4 feet upstream from the weir. In a suppressed weir, if the nappe is allowed to expand laterally after leaving the weir, the computed discharge by any of the formulas should be increased from one-fourth to one-half of 1 per cent.

Comparative discharge by various formulas over weirs of great height and length; no end contractions nor velocity of approach.[a]

Formula.	Coefficient C, for heads ranging from 0.20 to 4 feet.				Per cent of discharge by Francis formula for heads ranging from 0.20 to 4 feet.			
	0.20	0.50	1.00	4.00	0.20	0.50	1.00	4.00
Castel	3.4872	3.4872	3.4872	3.4872	104.616	104.616	104.616	104.616
Boileau	3.3455	3.3455	3.3455	3.3455	100.365	100.365	100.365	100.365
Weisbach	3.4025	.....	3.3136	.....	102.075	.....	99.408	.....
Francis	3.33	3.33	3.33	3.33	100.00	100.0	100.0	100.0
Fteley and Stearns	3.5004	3.3269	3.317	3.3109	105.012	99.807	99.51	99.327
Bazin	3.642684	3.406094	3.326696	3.26783	109.281	102.183	99.801	98.035
Fteley-Stearns-Francis	3.3800	3.3300	3.319	3.31375	101.400	99.90	99.570	99.412
Hamilton Smith	3.3972	3.3010	3.284	3.284	101.916	99.030	98.520	.....
Smith Francis	3.29	3.29	3.29	3.29	98.70	98.70	98.70	.....
Parmley	3.478	3.368	3.334	.....	104.340	101.040	100.020	.....
East Indian engineers	3.488	3.472	3.445	3.285	104.640	104.16	103.35	98.550

[a] Computed by H. R. Beebe, C. E.

Table showing comparative discharge per foot of crest for suppressed weirs of various lengths, heads, and velocities of approach.[a]

Length (L)	2	2	10	10	10
Height (P)	1	2	2	4	4
Head (D)	1.0	1.0	1.0	1.0	4
Approximate velocity of approach (v)	1.90	1.18	1.16	.68	2.15
Castel	3.7822	3.6127	3.6217	3.5308	30.3037
Boileau	3.8630	3.5484	3.5484	3.4144	30.9046
Francis	3.5373	3.4218	3.4218	3.3632	28.2983
Fteley and Stearns	3.7268	3.4729	3.4730	3.3669	29.7470
Bazin	3.7845	3.3766	3.3766	3,4002	29.7555
Fteley-Stearns-Francis	3.7297	3.4752	3.4752	3.3690	29.7000
Hamilton Smith	3.9220	3.6392	3.4872	3.3878	.....
Smith-Francis	4.0581	3.7109	3.4847	3.3876	31.573
Parmley	3.7924	3.5337	3.5337	3.3347	.....
Average	3.800	3.532	3.490	3.395	30.040

[a] Computed by H. R. Beebe, C. E.

COMPARISON OF VARIOUS VELOCITY OF APPROACH CORRECTIONS.

The various modes of correction for velocity of approach used by different investigators can be rendered nearly identical in form, varying, however, in the value of the coefficient α adopted.

Comparative coefficients of correction for velocity of approach for thin-edged weirs with end contractions suppressed.

Experimenter.	Value of α in the formula $H=D+\alpha\frac{v^2}{2g}$	Values of ω in the formula $K=1+\omega\left(\frac{a}{A}\right)^2$
Boileau	$\alpha=1.8$	
Lesbros	$\alpha=1.56$	
Fteley and Stearns	$\alpha=1.5$	
Francis	[a] $\alpha=1-\frac{2}{3}\sqrt{\frac{h}{D}}$	[b] $\omega=0.2489$
Bazin	$\alpha=1.69$ or $\frac{5}{3}$	$\omega=0.55$

[a] Emerson. [b] Hunking and Hart.

The above values were all derived from experiments on thin-edged weirs. Bazin's experiments covered the larger range of velocities and were most elaborate. It may be noted that the correction applied by Bazin is two and two-tenths times that of Francis for a given velocity

of approach. Bazin's correction is, in effect, an increase in the measured head of 1.69 times the velocity head, while Francis increases the measured head by an amount $\frac{2}{3}\sqrt{\frac{h}{D}}$ *less than* the velocity head according to Emerson's formula.

Ratio of the various corrections for velocity of approach for suppressed weirs.

	Bazin.	Fteley and Stearns.	Hamilton Smith.	Francis.
Bazin	1.000	1.127	1.271	2.2
Fteley and Stearns	.887	1.000	1.128	1.957
Hamilton Smith	.789	.887	1.000	1.739
Francis	.454	.511	.576	1.000

The factors in the above table are not strictly accurate, for the reason that the expressions used to deduce the equivalents from the different formulas are in some cases approximations. They serve to illustrate the relative magnitude of the different corrections for thin-edged weirs without end contractions. For thin-edged weirs with end contraction, Hamilton Smith uses the coefficient $\alpha=1.4$ and Fteley and Stearns give the coefficient $\alpha=2.05$.

There are no experiments available relative to the value of the velocity correction for other than thin-edged weirs. It is necessary, therefore, to utilize the values above given for weirs of irregular section. It will be seen that it matters little in what manner the correction for velocity of approach is applied, either by directly increasing the observed head, as in the formulas of Hamilton Smith and Fteley and Stearns, or by including the correction in the weir coefficient, as is done by Bazin, or by utilizing a special formula to derive the corrected head, after the manner of James B. Francis. The three methods can be rendered equivalent in their effect.

The important point is that the corrected result must be the same as that given by the author of the formula which is used to calculate the discharge. As to the relative value of the different modes of applying the correction, it may be said of that of Francis, that in its original form it is cumbersome, but it renders the correction independent of dimensions of the leading channel, as do also the formulas for correction used by Hamilton Smith, and Fteley and Stearns. Inasmuch as the velocity head is a function of the discharge, successive approximations are necessary to obtain the final corrected head by any one of these three formulas.

By using the Hunking and Hart formula the correction for the Francis weir formula becomes fairly simple, as it does not require the determination of the mean velocity of approach by successive approxi-

mations, but to apply this formula it is necessary to know the dimensions of the leading channel and of the weir section. The approximation given by Emerson is also much simpler than the original Francis formula.

Bazin's method of including the velocity correction in the coefficient makes the weir coefficients obtained by the experiments comparable one with another only when both the head and velocity of approach are the same in both cases.[a] His correction also involves the dimensions of the leading channel as factors. Obviously, in the case of many broad-crested weirs utilized for measuring flow, the dimensions of the leading channel can not be ascertained accurately and there is great variation of velocity in different portions of the section of approach. It becomes necessary that the correction should be in such a form that it is a function of the velocity and not of the channel dimensions.

It is to be noticed that where an attempt has been made in the weir experiments to eliminate velocity of approach effect from the coefficient the velocity has been nearly equalized by screens and has been determined by successive approximations. It is suggested that where the velocities vary widely they be determined by current meter in several subdivisions of the section, the approximate integral kinetic energy estimated, and a value of α selected depending on the ratio of $\frac{h'}{h}$ so obtained, where h is the velocity head corresponding to the mean velocity and h' is the velocity head which would result if the actual velocities were equalized. Inasmuch as the surface velocity usually exceeds the mean velocity in the channel of approach in about the same ratio that h' exceeds h, the suggestion is made by Hamilton Smith[b] that where the velocity of approach is unavoidably variable, or the boundaries of the current are uncertain, the surface velocity v_s be measured by floats and applied directly in the determination of the quantity h.

The variations in discharge over a thin-edged weir, by the different formulas, are often less than the difference in the correction for velocity of approach would indicate. In the formula of Fteley and Stearns, as compared with Francis, for example, the larger velocity correction is in part compensated by a smaller weir coefficient, and the same is true of the formulas of Hamilton Smith and Bazin for cases where the head is large.

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[a] See special discussion of the point, p. 63.

[b] Smith, Hamilton, Hydraulics, p. 84.

END CONTRACTIONS—INCOMPLETE CONTRACTION.

The formula for end contractions deduced by James B. Francis is very generally used. The correction is made to the length of weir, the result obtained being the length of a suppressed weir that will give the same discharge.

$$L = L' - b\,NH \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (40)$$

b = A coefficient, the value of which, deduced by Francis, is $b = 0.1$.

L' = Actual length of weir crest.

L = Length of equivalent suppressed weir crest.

N = Number of end contractions.

H = Effective head, feet.

The experiments of Fteley and Stearns,[a] while somewhat discordant, indicate an average value of b for heads from 0.3 to 1 foot, of about 0.1. The value of b apparently decreases as the head increases. It also decreases if the end contraction piece is so near the side of the channel as to render the contraction incomplete.

Hamilton Smith shows that side contractions and bottom or crest contraction are mutually related, and that the side width of the channel of approach should be fully three times the least dimension of the weir. Usually L is much greater than H, and the side width may be made at least as great as $3H$. The specification of Francis is, side width $= H$.

Smith's rule indicates that to provide complete contraction the area of leading section A must bear a relation to the area of weir section a depending upon the relative head and length of crest.

For three weirs of equal section a, the following values of A, the necessary channel-section area, are given:

$L' = 12$	$H = 1$	$a = 12$	$A = 72 = 6a$
$L' = 4$	$H = 3$	$a = 12$	$A = 264 = 2.2a$
$L' = 1$	$H = 12$	$a = 12$	$A = 105 = 8.7a$

Hamilton Smith prefers to use separate coefficients for suppressed weirs from those for contracted weirs, the relation between the coefficients being expressed by the formula

$$C_p = C_c\left(1 + z\frac{S}{R}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

C_p = Coefficient for partially suppressed weir, as with complete suppression on sides and full contraction at bottom.

[a] Fteley and Stearns, Experiments on the flow of water, etc.: Trans. Am. Soc. C. E., vol. 12, pp. 108–113.

C_c = Coefficient for completely contracted weir.
X = Least dimension of weir, whether L or H.
R = Wetted perimeter of weir $= L+2H$.
Y = Distance from any side of weir to the respective side of channel, where there is partial suppression.
S = Length of sides on which there is partial suppression.

Smith's values of contraction coefficient z in formula 31 are

Y/X	z
3	0.000
2	.005
1	.025
½	.06
0	.16

The ratio Y/X approximately measures the amount of contraction.[a]

Bazin does not give a formula for weirs with end contractions. The Bazin formula may be applied to weirs in which the height of weir is so small that the bottom contraction is partially suppressed. The Bazin coefficient then includes:

1. Effect of contraction from surface curve.
2. Effect of crest contraction and its modification by both velocity of approach and by partial suppression, if any.
3. Effect of velocity of approach proper.
4. Effect of distribution of velocities in channel of approach.
5. Loss of head from friction and eddies.

As the Bazin weirs were very low, and these factors go to increase the correction necessary, it will be seen that the relatively large velocity of approach correction required by Bazin's formula may be readily accounted for.

The experiments of Flinn and Dyer on the Cippoletti weir (see p. 48) indicate that the effect of end contraction may be somewhat greater than that indicated by the Francis formula. Any experiments in which similar volumes of water have been successively passed over weirs with and without end contractions may be utilized to determine the effect of such contractions.

It may be added that a more elaborate study of end contractions is desirable. It is to be borne in mind, however, that to secure greater accuracy in this regard a more complicated or variable correction than that of Francis must probably be used, and the result will be to greatly increase the labor of weir computations in the interest of what is usually a comparatively small matter, the better remedy being probably the use of weirs with end contractions suppressed, wherever practicable.

[a] Smith, Hamilton, Hydraulics, pp. 118-123. Smith's critical discussion of this subject will be found of value in calculating discharge for weirs with partially suppressed contraction either at sides or bottom.

COMPOUND WEIR.

A weir with a low-water notch depressed below the general crest level may sometimes be used to advantage in gaging small, variable streams. The discharge over such a weir, constructed with end contractions on both sections, can be calculated as for two separate weirs, the lower short section having end contractions for all heads. The flow over the two upper sections is computed as for a suppressed weir.

Such a weir has been used for the determination of the low-water flow of very small streams, for which purpose it is well adapted, the entire stream when at low stages flowing in the central notch, in a stream relatively deep and narrow.

The measurement of very thin sheets of water on a broad weir is subject to peculiar difficulties, including uncertainty of coefficient, adhesion of nappe to weir face, dispersion by winds, and a large percentage error in the results if there is a small error in measuring the head.

TRIANGULAR WEIR.

GENERAL FORMULA.

Referring to fig. 4, we may write

$$l : H-y :: L : H.$$

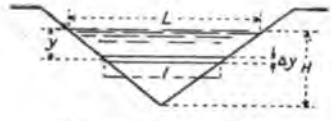


FIG. 4.—Triangular weir.

Substituting, in equation (4),

$$Q=\int_0^H \sqrt{2gy}\,\frac{L(H-y)}{H}\,dy$$

$$=\frac{4}{15}\,L\,\sqrt{2g}\,H^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

THOMSON'S EXPERIMENTS.

The mean coefficient of contraction for a thin-edged triangular weir deduced experimentally by Prof. James Thomson, of Belfast, is $M=0.617$,[a] the formula being

$$Q=\frac{4}{15}ML\,\sqrt{2g}\,H^{\frac{3}{2}}=1.32LH^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad (43)$$

[a] British Association Report, 1858 (original not consulted). Merriman gives the mean value of M for heads between 0.2 and 0.8 foot as 0.592.

For a right-angled notch,

$$L=2H \text{ and } Q=2.64H^{\frac{5}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (44)$$

The length of the contracting edges in a triangular notch being proportional to the depth, it is believed that the coefficient of discharge is somewhat more constant than for a rectangular weir.[a]

TRAPEZOIDAL WEIR.

The discharge in this case may be determined directly from the integral formula (4) as for a triangular weir, by integrating between the limits AD and CE, fig. 5. It may also be derived as follows:

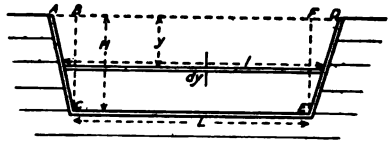


FIG. 5.—Trapezoidal weir.

z=slope of one side to the vertical.

$$Q=\int_{y=o}^{y=H} \sqrt{2gy}\,[L+2z(H-y)]\,dy$$

By integration,

$$Q=\frac{2}{3}\sqrt{2g}\,LH^{\frac{3}{2}}+\frac{8}{15}z\sqrt{2g}\,H^{\frac{5}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (45)$$

in which coefficients of contraction for the horizontal crest and for the end slopes must be introduced.

THE CIPPOLETTI TRAPEZOIDAL WEIR.

The discharge over a trapezoidal without contraction would be the sum of that for a rectangular weir added to that for two triangular weirs forming the ends. From the experiments of James B. Francis[b] it appears that each end contraction reduces the effective length of the weir $0.1H$. The contraction decreases the discharge by the amount

$$Q=\frac{2}{3}\,M\times 0.1H\,\sqrt{2g}\,H^{\frac{3}{2}}=\frac{2}{3}\,\frac{M}{10}\,\sqrt{2g}\,H^{\frac{5}{2}}$$

If the ends of the weir, instead of being vertical, are inclined outward in such manner that the discharge through the added area counterbalances the decrease from the end contraction, then the effective

[a] The coefficient 2.64 is the same as that deduced for broad crest weirs with stable nappe. A table of values of $2.64H^{\frac{5}{2}}$ is given on page 177, which may be applied in calculating flow over triangular weirs.
[b] Lowell Hydraulic Experiments.

length of the weir will remain constant as the head increases, the same as in a suppressed weir. The discharge through the end triangle ABC will be, from equation (42),

$$Q=\frac{4}{15}Mz\sqrt{2g}H^{\frac{3}{2}}$$

Where z is the width or base of the end triangle. Equating the two expressions for Q, and solving for z, we find, assuming M to have the same value in both cases,

$$z=\frac{1}{4}H \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (46)$$

This condition defines the Cippoletti weir.[a]

CIPPOLETTI'S FORMULA.

Cippoletti derived his formula from a discussion of the experiments of James B. Francis, selecting a coefficient 1 per cent greater, making

$$Q=\frac{2}{3}\times 0.629\ LH\sqrt{2g}H=3.367LH^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad (47)$$

L is the length of the crest or base of the trapezoid.

Flinn and Dyer[b] experimented at the testing flume of the Holyoke Water Power Company by passing the same volume of water successively over a trapezoidal experimental weir and over the gaging weir of the turbine testing flume 19.7 feet downstream. The latter, it is stated, complied in form with Francis's specifications.

The depths were observed by hook gage; eleven readings, as a rule, being taken and their arithmetical mean used for the determination of a head. The thirty-two series of valid experiments range from 0.3 foot depth on a weir with sill length of 3 feet to a head of 1.25 feet on a sill 9 feet long.

The discharge over the standard weir was calculated by the formulas of J. B. Francis and of Hamilton Smith. The correction for velocity of approach at the experimental weir was made by the formula of Hamilton Smith, for use with contracted rectangular weirs,

$$H=D+1.4h.$$

Flinn and Dyer's coefficients are as follows:

Mean of 32 experiments, $C=3.283$

Mean after rejecting 5 diminished weights, $C=3.301$

In general, the coefficient diminished as the head increased, suggesting that the end inclination should slightly exceed $\frac{1}{4}H$ in the Cippoletti weir, to provide complete compensation, and that the end contraction

[a] First described by Cesare Cippoletti in Canal Villoresi, Modulo per la Dispensa delle Acque, 1887.

[b] Flinn, A. D., and Dyer, C. W. D., The Cippoletti trapezoidal weir: Trans. Am. Soc. C. E., vol. 32, 1894, pp. 9-33.

coefficient in the trapezoidal weir may be greater than $0.1H$, as used by Francis.

The question is complicated by velocity of approach. For example, had the Francis velocity-correction formula been used by Flinn and Dyer, their values of C would have been larger. As a tentative conclusion it is probable that the application of either the Francis formula with his velocity-head correction or the Flinn and Dyer coefficient with the Smith velocity correction will, when applied to a Cippoletti weir, give results as accurate as the precision of the coefficients will justify.

REQUIREMENTS AND ACCURACY OF WEIR GAGINGS.

PRECAUTIONS FOR STANDARD WEIR GAGING.

Certain specifications were laid down by James B. Francis as guides in cases where the utmost precision is desired in weir measurements.[a] The limits of applicability of the weir have been greatly extended since 1852, and some of the uncertainties as to the effect of various modifications of weir construction have been removed.

In general, for standard thin-edged weirs—

1. The upstream crest edge should be sharp and smooth.
2. The overflowing sheet should touch only the upstream crest corner.
3. The nappe should be perfectly aerated.
4. The upstream face of the weir should be vertical.
5. The crest should be level from end to end.
6. The measurements of head should show the true actual elevation of water surface above the level of the weir crest.
7. The depth of leading channel should be sufficient to provide complete crest contractions, and, if they are not suppressed, the width of channel should be sufficient to provide complete end contractions.
8. A weir discharging from a quiet pond is to be preferred. If this is not available, the velocity of approach in the leading channel should be rendered as uniform as possible and correction made therefor by the method employed by the experimenter in deriving the formula.

In order to fulfill these requirements, certain secondary conditions are necessary. The depth on the weir should be measured at a point far enough upstream from the crest to be unaffected by the surface curvature, caused by the discharge.

[a] Francis, J. B., Lowell Hydraulic Experiments, pp. 133-135.

The distance upstream to the point of measuring the head has been as follows:

Distance upstream from weir to gage used by various experimenters.

Experimenter.	Date.	Distance upstream, in feet.
Poncelet and Lesbros	1828	11.48
Lesbros	1834	11.48
Francis	1852	6.00
Hamilton Smith, jr	1874–1876	7.60
Fteley and Stearns	1878	6.00
Bazin	1886	16.40

Six feet upstream from crest is a distance frequently used, but this may be insufficient for suppressed weirs, and also for those having irregular cross sections or upstream slopes. Boileau considered the origin of the surface curvature to be at a distance from the weir equal to about 2.5 times the height of crest above the bottom of the channel of approach, indicating that for a suppressed weir the head should be measured at least this distance from the crest.[a] For a weir discharging from a still pond the head can be measured at any considerable distance from the weir. Hamilton Smith[b] states that, for weirs with full contraction, H can be measured at any convenient point from 4 feet to 10 feet from the crest.

The head may be measured directly by a graduated scale or hook gage, or by means of a piezometer tube having its orifice flush with the side wall of the leading channel, and at right angles to the direction of flow of the water.

The depth of the leading channel in Francis's experiments was 4.6 feet below crest, and Francis lays down the rule that the depth of the leading canal should be at least three times the head on the weir. Hamilton Smith fixes the minimum depth of the leading channel below the crest at $2H$.

Fteley and Stearns[c] state that the depth of the leading channel below weir crest should be at least 0.5 foot, in order that correction for velocity of approach may be reliably made for depths occurring in their measurements, and that a greater depth of leading channel is to be preferred.

To provide complete end contractions, Francis states that the distance from the side of the channel of approach to the end of the weir overflow should be at least equal to the depth on the weir. Hamilton

[a] Fteley and Stearns, Experiments on the flow of water, etc.: Trans. Am. Soc. C. E., vol. 12, p. 47.
[b] Smith, Hamilton, Hydraulics, pp. 129–131.
[c] Ibid., pp 112–114.

h considers that the distance from the end of the weir to the side ıe channel should be at least $2H$, and that the depth of channel v crest, also the side distance, should in no case be less than 1

Francis further specifies that the length of weir crest should least three times the depth of overflow. The nappe should not lowed to expand laterally immediately below a suppressed weir. order that the nappe may be perfectly aerated, Francis considers the fall below crest level on the downstream side should be not than $\frac{1}{2}H$, increasing for very long weirs or in cases where the stream channel is shallow. He found, however, no perceptible ence in the discharge for a head of 0.85 foot, whether the water e downstream side was 1.05 feet or 0.0255 foot below crest level. y and Stearns and Hamilton Smith agree that, if the water is

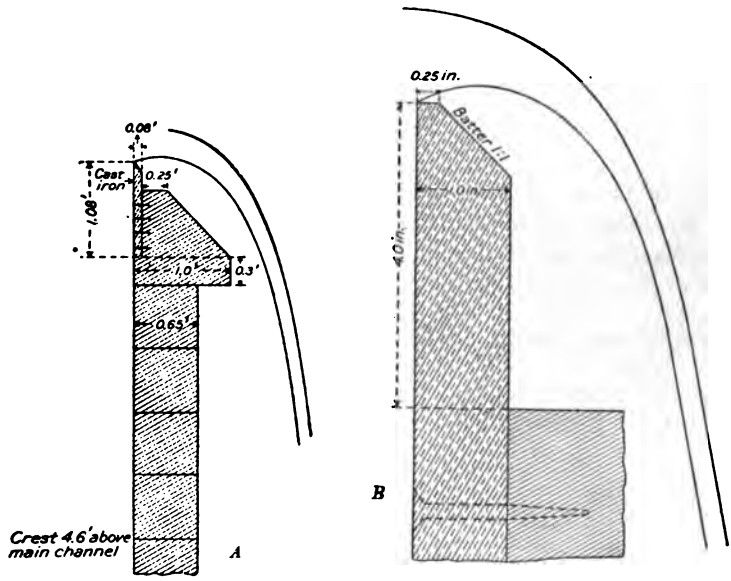


FIG. 6.—Sections of the Francis weir. *A*, General section of weir; *B*, detail of crest.

below, it may rise to crest level on downstream side of weir ıut sensible error, and Fteley and Stearns add that a weir may be ıerged to a depth of 15 per cent of the head without an error eding 1 per cent.

e thickness of crest lip is immaterial so long as the edge is sharp ıquare and the nappe cuts free and is freely aerated. The latter itions require, however, that the crest shall be thin, especially e the head is slight.

ɡ. 6 shows cross sections of the crest of the weir used by James B. cis at the Lower Merrimac locks at Lowell, in 1852, in deriving ɔrmula. The crest consisted of a cast-iron plate 13 inches wide inch thick, planed true and smooth on all surfaces. Its upper

edge was chamfered on the downstream side at an angle of 45° to a thickness of 0.25 inch at the edge. As shown, the nappe cut clear from the top of the crest in an unbroken sheet. The lowest head used by Francis was over 0.5 foot. For very low heads the crest lip should be thinner. A wooden crest tends, by capillary attraction, to cause the nappe to adhere to the flat top surface under low heads. A wooden crest is cheap, easily adjusted, and convenient for temporary use, but it will, in time, tend to become somewhat rounded, reducing the vertical contraction of the nappe.

A cast-iron crest will usually have to be made to order. A large steel angle bar may often be obtained from stock sizes of the rolling mills more cheaply. Such a bar, with legs, say 3 and 6 inches, respectively, with the 6-inch flat face planed and its edge trued, will form a rigid and permanent crest. The 3-inch leg may be bolted to the top of the timbers forming the body of the weir.

It may be added that approximate corrections for rounding of upstream corner of the crest, inclination of the weir upstream or downstream, or incomplete contractions can be made from data now available. In constructing gaging weirs preference, however, should be given to those forms which render the determination of the discharge the most simple, and the extent to which the preceding specifications may be departed from judiciously will depend upon the exigencies of the case and the purposes for which the results are desired.

PLANK AND BEAM WEIRS OF SENSIBLE CREST WIDTH.

Experiments on weirs with crest boards 1, 2, or 4 inches in thickness were made by Blackwell, Fteley and Stearns, and Bazin. The results show that for depths exceeding 1.5 to 2 times the crest width the nappe will break free, and if properly aerated the coefficient will then be identical with that for a thin-edged weir.

When the nappe adheres to the crest the coefficients are very uncertain for such weirs, adhesion of nappe to downstream face of crest and modified aeration entering to give divergent values.

The precise stage at which the change from an adhering to a free nappe or the reverse occurs is not constant, but varies with velocity of approach and with rate of change of the head as the changing point is approached, being different for a sudden and for a gradual change, and also when the point of change is approached by an increasing as compared with a decreasing head.

REDUCTION OF THE MEAN OF SEVERAL OBSERVATIONS OF HEAD.

In measuring a constant volume of water, several observations of the head on the weir are desirable, the accuracy of the result, according to the theory of least squares, being proportional to the square root of the number of observations.

In weir experiments it is often impossible to maintain a perfectly iform head or regimen. If the variations are minute the arithmetl mean may be used directly. If the variations are of wider range, if the utmost precision is required, the following correction rmula of Francis may be applied:[a]

Let D_1, D_2, D_3, etc., D_n represent the several successive observed heads.

Let t_1, t_2, t_3, etc., t_n represent the corresponding intervals of time between the several observations.

Let T represent their sum, or the total time interval.

Q=the total volume of water flowing over the weir in the time T.

D=the mean depth on the weir that would discharge the quantity Q in the time T.

L=the length of weir crest.

C=the weir coefficient.

We have, very nearly,

$$Q=\frac{t_1}{2}\,CLD_1^{\frac{3}{2}}+\frac{t_1+t_2}{2}\,CLD_2^{\frac{3}{2}}+\frac{t_2+t_3}{2}\,CLD_3^{\frac{3}{2}}+\text{etc.}+\frac{t_n}{2}\,CLD_n^{\frac{3}{2}}$$

Also,

$$Q=TCLD^{\frac{3}{2}}.$$

Equating, eliminating the common factor CL, and solving for D, we ve

$$D=\left\{\frac{1}{T}\left(\frac{t_1}{2}\,D_1^{\frac{3}{2}}+\frac{t_1+t_2}{2}D_2^{\frac{3}{2}}+\frac{t_n+t_3}{2}D_3^{\frac{3}{2}}+\text{etc.}+\frac{t_n}{2}D_n^{\frac{3}{2}}\right)\right\}^{\frac{2}{3}} \qquad (48)$$

EFFECT OF ERROR IN DETERMINING THE HEAD ON WEIRS.[b]

Consider the formula

$$Q=CLH^{\frac{3}{2}}.$$

Differentiating, we have

$$dQ=\frac{3}{2}\,CL\sqrt{H}\,dH.$$

The error of any gaging when $H+dH$ is taken as the head instead the true head H being used will be dQ, and the ratio of this quany to the true discharge Q will be

$$\frac{dQ}{Q}=\frac{3CL\sqrt{H}}{2CLH^{\frac{3}{2}}}\,dH=\frac{3}{2}\,\frac{dH}{H} \quad . \quad . \quad . \quad . \quad . \quad (49)$$

This formula will give nearly the correct value of the error if the crement dH approaches an infinitesimal.

Francis, J. B., Lowell Hydraulic Experiments, p. 113.

Rafter, G. W., On the flow of water over dams: Trans. Am. Soc. C. E., vol. 44, p. 686; data here en based on discussion by Walter C. Parmley.

In the following table is shown the effect of errors of one thousandth, five thousandths, one hundredth, and five hundredths foot, respectively, for various heads. This clearly illustrates both the necessity of proper care and the folly of ultra precision in measuring the relatively large values of H with which we are mainly concerned. The curves of error on Pl. II are equilateral hyperbolas, which have been reduced to straight lines by plotting on logarithmic scales.

Percentage error in discharge resulting from various errors in the measured head on weirs.

Head, in feet.	Error in measured head, in feet.			
	0.001	0.005	0.01	0.05
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
0.1	1.5	7.5	15	.....
.5	.3	1.5	3	15
1.0	.15	.75	1.5	7.5
5.0	.03	.15	.3	1.5
10.0	.015	.075	.15	.75

An error of a half-tenth foot under 5 feet head causes the same error in the result as an error of one-half hundredth foot with a head of one-half foot.

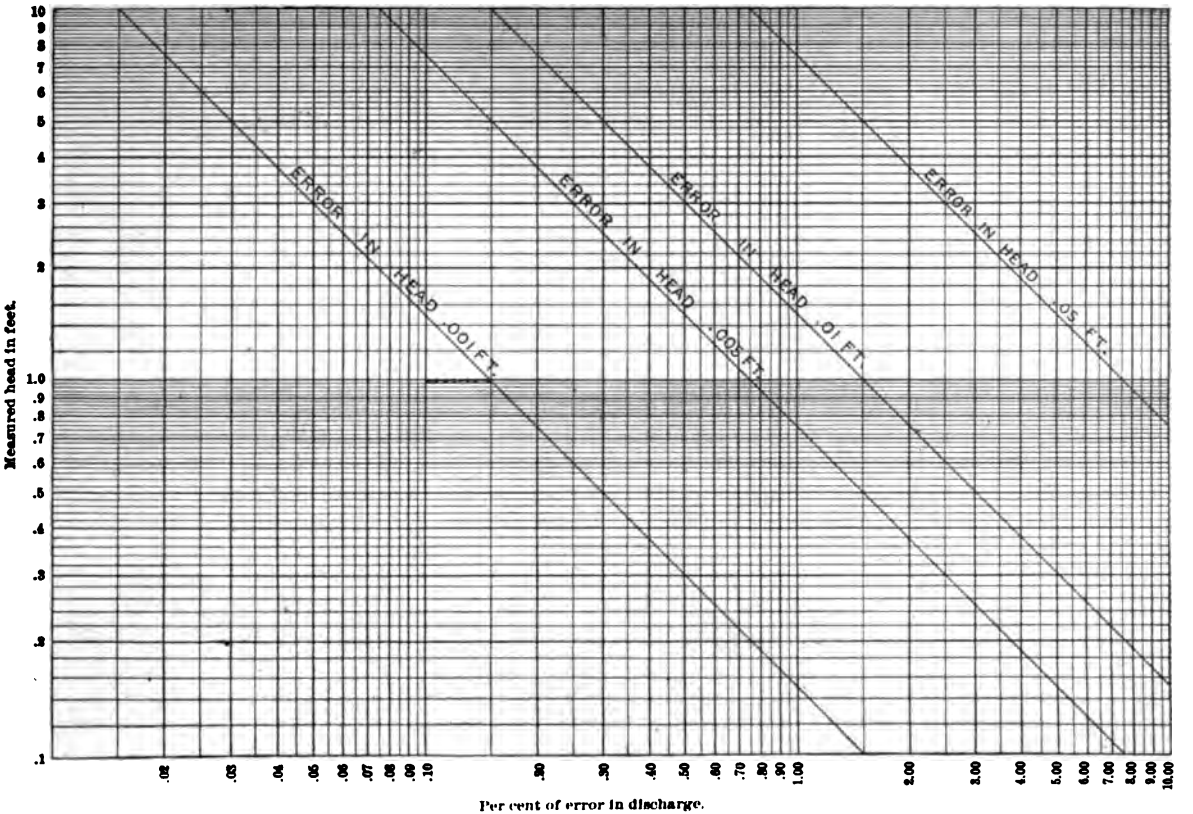
In weir experiments it is important to know the effect of an error in head H on the resultant coefficient of discharge C. The error in C is evidently equivalent to the error in Q found above, where H is constant.

ERROR OF THE MEAN WHERE THE HEAD VARIES.

In determining the volume of flow over dams where gaging records are kept, the method usually pursued has been to have readings taken twice daily, as at morning and evening, showing the depth flowing over the crest of the dam. The average of the two readings for each day has been found and the volume of flow corresponding to this average head has been taken as the mean rate of flow over the dam for the day.

It is evident, however, that as the discharge varies more rapidly than the head (usually considered to be proportional to the three-halves power of the head), the volume of discharge obtained as above described will be somewhat less than the amount which actually passes over the dam. The following analysis has been made to show the magnitude of the error introduced by using the above method.

Assuming that the initial depth on the crest of the dam is zero, but increases at a uniform rate to H_1 at the end of a time interval T, the


ERROR IN HEAD .001 FT.
ERROR IN HEAD .002 FT.
ERROR IN HEAD .01 FT.
ERROR IN HEAD .05 FT.
Measured head in feet.
10
9
8
7
6
5
4
3
2
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.02
.03
.04
.05
.06
.07
.08
.09
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Per cent of error in discharge.

mean head deduced from observations at the beginning and end of the period would be $\frac{1}{2} H_1$, the head at any time t would be

$$H=ft$$

where f is a constant.

We may write the usual formula for weir discharge $Q=CLH^{\frac{3}{2}}$; then, if the head varies from zero to H_1, the total volume of flow in the time T will be

$$Q_t=\int_0^T Qdt=CLf^{\frac{3}{2}}\int_0^T t^{\frac{3}{2}}dt=\frac{2}{5}CLf^{\frac{3}{2}}T^{\frac{5}{2}} \quad . \; . \; . \quad (50)$$

The total discharge corresponding to the average head $\frac{1}{2} H_1$ is

$$Q_{av}=CL\left(\frac{H_1}{2}\right)^{\frac{3}{2}}T=CL\left(\frac{f}{2}\right)^{\frac{3}{2}}T^{\frac{5}{2}} \quad . \; . \; . \; . \quad (51)$$

The ratio of the discharge is

$$\frac{\text{Volume by average head}}{\text{Actual volume}}=\frac{Q_{av}}{Q_t}=\frac{\left(\frac{1}{2}\right)^{\frac{3}{2}}}{\frac{2}{5}}=0.8840 \quad . \; . \quad (52)$$

It appears that where the initial or terminal head is zero the volume of flow determined by using the average head will be 11.6 per cent too small. This percentage of error is the same whatever may be the maximum head H_1 and whether the stream is rising or falling. It is also independent of the rate of change in the head.

Conditions like those above discussed occur at milldams during the season of low water, when the pond is allowed to fill up at night and the water is drawn down to crest level or below during the day when mills are running.

The following example will illustrate. Suppose a sharp-crested weir without end contractions, with crest 1 foot long, on which the water rises to a depth of 1 foot in a period of 10 seconds—

Mean depth on a weir with varying head.

Time, in seconds	1	2	3	4	5	6	7	8	9	10
Head, in feet, at end of each second	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
Average head for period	.05	.1	.15	.2	.25	.3	.35	.4	.45	.5
Average head, second to second	.05	.15	.25	.35	.45	.55	.65	.75	.85	.95

Using the average head during each second the volume of flow may be approximately integrated by finite differences, as follows, the discharge being taken from Francis's tables:

Discharge over a weir with varying head.

Time, in seconds.	Average head, in feet.	Discharge, in second-feet.
0 to 1	0.05	0.037
1 to 2	.15	.194
2 to 3	.25	.416
3 to 4	.35	.690
4 to 5	.45	1.005
5 to 6	.55	1.358
6 to 7	.65	1.745
7 to 8	.75	2.163
8 to 9	.85	2.609
9 to 10	.95	3.083
Total.....	.....	13.30

The average head for the entire period, 0.5 foot, gives a discharge for 10 seconds of 11.773 second-feet, or 88.5 per cent of that given above, the numerical result agreeing closely with that obtained by analysis. The volume of flow from average head equals seven-eighths of the true integral volume of flow, approximately.

If there is an initial head H_0, then when the head varies uniformly,

$$H = H_0 + ft$$
$$Q = CLH^{\frac{3}{2}} = CL\,(H_0 + ft)^{\frac{3}{2}}.$$

The total volume of flow in time T will be

$$Q_t = \int_0^T Q dt = CL \int_0^T (H_0 + ft)^{\frac{3}{2}}\, dt = \frac{2}{5f} CL \left(H_0 + fT\right)^{\frac{5}{2}} - \frac{2}{5f} CLH_0^{\frac{5}{2}}.$$

The average head during time T is

$$H_{av} = H_0 + \frac{1}{2} fT$$

The total volume of flow corresponding to this head is

$$Q_{av} = CL \left(H_0 + \frac{1}{2} fT\right)^{\frac{3}{2}} T$$

The ratio of the actual or integral discharge to the discharge by the average head is

$$\frac{\text{Volume by average head}}{\text{Integral volume}}=\frac{5}{2}f\frac{\left(H_o+\frac{1}{2}fT\right)^{\frac{3}{2}}T}{\left[\left(H_o+fT\right)^{\frac{5}{2}}-H_o^{\frac{5}{2}}\right]} \quad . \quad (53)$$

The value of this ratio is independent of the coefficient or length of weir, but varies with the rate of change of head.

WEIR NOT LEVEL.

If the crest of a gaging weir is not truly horizontal, but is a little inclined, the discharge may be closely approximated by the use of the average crest depth H in the ordinary formula, or more precisely by the formula below, applicable also to weirs of any inclination.

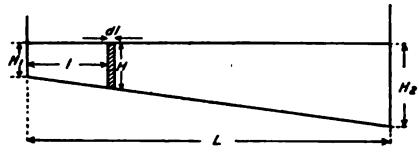


FIG. 7.—Inclined weir

The flow through the elementary width dl is

$$dQ=CH^{\frac{3}{2}}dl$$

$$H=H_1+\frac{H_2-H_1}{L}l$$

$$\text{Total discharge}=Q=\int_0^L CH^{\frac{3}{2}}\,dl=C\int_0^L\left(H_1+\frac{H_2-H_1}{L}l\right)^{\frac{3}{2}}dl$$

Integrating,

$$Q=\frac{2CL}{5\left(H_2-H_1\right)}\left(H_2^{\frac{5}{2}}-H_1^{\frac{5}{2}}\right) \quad . \quad . \quad . \quad . \quad . \quad (54)$$

In this formula either the mean coefficient deduced by Thomson (see p. 46) for a triangular weir, in which $\frac{2}{5}C=1.32$, or that of Francis, in which $\frac{2}{5}C=1.332$, may be used. If there are end contractions, the net length,

$$L=L'-0.2\left(\frac{H_2+H_1}{2}\right),$$

should be used.

The discharge using the average head,

$$H_a = \frac{H_2 + H_1}{2},$$

is

$$Q = CL\left(\frac{H_2 + H_1}{2}\right)^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (55)$$

The extent of variation from the true discharge resulting from the use of formula (55) in place of the integral formula (54) is illustrated by the following:

Let $L = 10$ feet, $H_a = 1.0$ foot, $\frac{2}{5}C = 1.332$.

Discharge by (55) for average head $= 33.30$ cubic feet per second.
If $H_2 - H_1 = 0.01$ foot—true discharge, $Q = 33.30$ cubic feet per second.
If $H_2 - H_1 = 0.10$ foot—true discharge, $Q = 33.30$ cubic feet per second.
If $H_2 - H_1 = 0.50$ foot—true discharge, $Q = 33.54$ cubic feet per second.

In general, since the discharge varies more rapidly than the head, the effect of calculating the discharge from the average head will be to give too small discharge, the error increasing with the variation in crest level.

Hence the discharge obtained by using the average crest level for a weir having an inclined or uneven crest will be somewhat deficient. The magnitude of the variations in height of the crest will determine whether the average profile can be used or whether the crest should be subdivided into sections, each comprising portions having very nearly the same elevation (whether adjacent or not), and the discharge over each section computed as for a separate weir.

In general it may be stated that the error in the value of Q increases directly in proportion as the ratio of the difference in the limiting heads to the average head is increased.

CONVEXITY OF WATER SURFACE IN LEADING CHANNEL.

If there are wide variations in velocity in the measuring section, the level of the water surface may be affected, since water in motion exerts less pressure than when at rest.

Conditions of equilibrium cause the swift-moving current to rise above the level of the slower-moving portions. If the head is measured near still water at the shore, the result may be slightly too small.

The difference in height[a] may be expressed in the form,

$$D_2 - D_1 = r\frac{v_2^2 - v_1^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (56)$$

The coefficient r is often assumed equal to unity, but evidently varies with the distribution of velocities whose resultant effect it measures.

[a] Humphreys and Abbot, Physics and Hydraulics of the Mississippi River, 1876, p. 320.

RESULTS OF EXPERIMENTS ON VARIOUS FORMS OF WEIR CROSS SECTIONS.

THE USE OF WEIRS OF IRREGULAR SECTION.

Many cases arise where it is desired to estimate, approximately, at least, the flow over dams of peculiar cross section.

The construction of so-called standard or thin-edged weirs that shall be permanently useful to measure the flow of large and variable streams is so difficult and expensive as to be frequently impracticable. Existing milldams often afford a convenient substitute. In the following pages are presented the results of the leading experiments to determine proper coefficients for "irregular" weirs, followed by a grouping of experiments on similar models, whether all by one experimenter or not. The data are not always as complete or consistent as could be desired, but the need for fair working coefficients is very great, and, in the line of making use of all the available information, the several diagrams of comparison and the conclusions therefrom are presented, with the understanding that these are not final, although it is quite certain that the laws of coefficient variation are correctly outlined by the data at present available, and they form, therefore, a safe working hypothesis.

Weir models of irregular section are calibrated in order that existing dams of similar cross section may be used for stream gaging. It becomes necessary to calibrate the experimental models for a wider range of heads than has commonly been employed in experiments on standard thin-edged weirs, in order that the range of rise and fall of the stream from low water to high may be included.

While the recent experimental data include heads as great as from 4 to 6 feet, yet it is often necessary to determine the discharge for still greater heads, and experiments on certain forms with heads up to 10 or 12 feet are needed.

In this connection the greater relative facility of securing accurate results with weirs for high than for low heads may be noted.

The proportional error resulting from variations in crest level, as well as uncertainties as to the nappe form and consequent value of the coefficient, largely disappear as the head increases. The effect of form of crest and friction is also relatively diminished. It is probably true that the coefficients for many ordinary forms of weir section would tend toward a common constant value if the head were indefinitely increased. The above facts render milldams especially useful for the determination of the maximum discharge of streams. Dams can be used for this purpose when the presence of logs and drift carried down by the flood preclude the use of current meters or other gaging instruments.

MODIFICATIONS OF THE NAPPE FORM.

The elaborate investigations of Bazin relative to the physics of weir discharge set forth clearly the importance of taking into consideration the particular form assumed by the nappe. This is especially true in weirs of irregular section in which there is usually more opportunity for change of form than for a thin-edged weir. In general the nappe may—

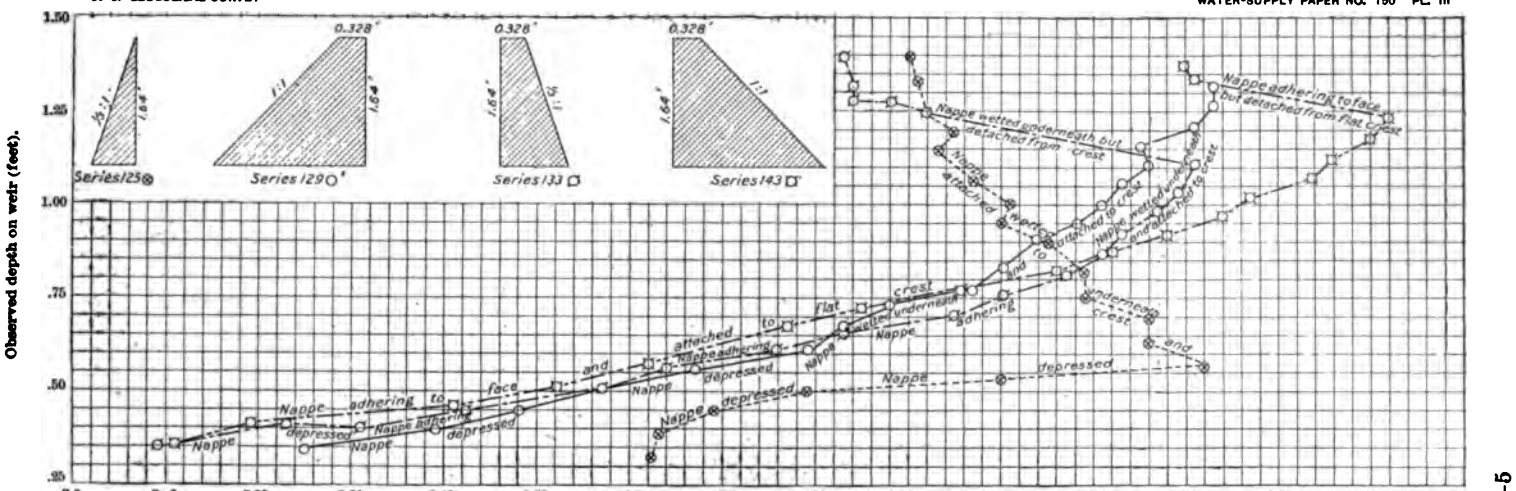
1. Discharge freely, touching only the upstream crest edge.
2. Adhere to top of crest.
3. Adhere to downstream face of crest.
4. Adhere to both top and downstream face.
5. Remain detached, but become wetted underneath.
6. Adhere to top, but remain detached from face and become wetted underneath.
7. In any of the cases where the nappe is "wetted underneath" this condition may be replaced by a depressed nappe, having air imprisoned underneath at less than atmospheric pressure.

The nappe may undergo several of these modifications in succession as the head is varied. The successive forms that appear with an increasing stage may differ from those pertaining to similar stages with a decreasing head. The head at which the changes of nappe form occur vary with the rate of change of head, whether increasing or decreasing, and with other conditions.

The law of coefficients may be greatly modified or even reversed when a change of form takes place in the nappe.

The effect of modifications of nappe form on various irregular weir sections is shown in Pl. III. The coefficients are those of Bazin and include velocity of approach. The coefficient curve for any form of weir having a stable nappe is a continuous, smooth line. When the nappe becomes depressed, detached, or wetted underneath during the progress of an experiment, the resulting coefficient curve may consist of a series of discontinuous or even disconnected arcs terminating abruptly in "*points d'arrêt*," where the form of nappe changes. The modifications of nappe form are usually confined to comparatively low heads, the nappe sometimes undergoing several successive changes as the head increases from zero until a stable condition is reached beyond which further increase of head produces no change. The condition of the nappe when depressed or wetted underneath can usually be restored to that of free discharge by providing adequate aeration.

The weir sections shown in Pl. III are unusually susceptible of changes of nappe form. Among weirs of irregular section there is a large class for which, from the nature of their section, the nappe can assume only one form unless drowned. Such weirs, it is suggested, may, if properly calibrated, equal or exceed the usefulness of the thin-edged



Value of the coefficient $C = m\sqrt{2g}$ (m being the original Bazin coefficient).

VARIATIONS IN WEIR COEFFICIENT WITH CHANGE OF NAPPE FORM.

ir for purposes of stream gaging, because of their greater stability section and because the thin-edged weir is not free from modifica- n of nappe form for low heads.

As an example, Bazin gives the following coefficients applying to thin-edged weir 2.46 feet high, with a head of 0.656 foot, under rious conditions:

Condition of nappe.	Bazin coefficient m.	$C=m\sqrt{2g}$	Per cent of the Francis coefficient.
ee discharge, full aeration	0.433	3.47	104.1
ppe depressed, partial vacuum underneath	.460	3.69	110.7
ppe wetted underneath, dowr stream water evel, 0.42 foot below crest	.497	3.99	119.7
ppe adhering to downstream face of weir, res- sault at a distance	.554	4.45	133.5

These coefficients include velocity of approach effect, which tends magnify their differences somewhat. There is, however, a range 25 per cent variation in discharge between the extremes.[a]

The departure in the weir coefficient from that applying to a thin- ged weir, for most forms of weirs of irregular section, results from me permanent modification of the nappe form. Weirs with sloping stream faces reduce the crest contraction, broad-crested weirs cause herence of the nappe to the crest, aprons cause permanent adherence the nappe to the downstream face.

EXPERIMENTAL DATA FOR WEIRS OF IRREGULAR CROSS SECTION.

The only experiments on irregular or broad-crested weirs in which e discharge has been determined volumetrically are those of Black- ell on weirs 3 feet broad, of Francis on the Merrimac dam, and of e United States Geological Survey for lower heads, on various forms section. So far as the writer is aware, all other such experiments ave been made by comparison with standard weirs.

In the following pages are included the results of the experiments f Bazin on 29 forms of cross section; also those of the United States eep Waterways Board under the direction of George W. Rafter, and ose of John R. Freeman at Cornell University hydraulic laboratory. he results of 20 series of experiments, chiefly on weirs with broad and gee crest sections, made under the writer's direction at Cornell Uni- ersity hydraulic laboratory, are here for the first time published.

[a] Bazin's general discussion of the above and other modifications of the coefficient has been trans- ed by the writer, and may be found in Rafter's paper, On the flow of water over dams: Trans. n. Soc. C. E., vol. 44, pp. 254-261.

As it has been necessary to reduce the experimental data to a uniform basis for purposes of comparison the original data, together with the results obtained by recalculation, have been included for the Bazin, United States Deep Waterways, and Freeman experiments.

BASE FORMULA FOR DISCHARGE OVER WEIRS OF IRREGULAR CROSS SECTION.

Precedent to the opening of the hydraulic laboratory of Cornell University the most elaborate experiments on weirs of irregular cross section were those of Bazin. His experiments were all reduced in such manner as to include the velocity of approach correction in the discharge coefficient.

In America the formula most commonly used is that adopted by James B. Francis, in which velocity of approach is eliminated from the coefficient by correcting the head, thus reducing the conditions as nearly as possible to the basis of no velocity of approach before applying the formula.

In order to render Bazin's results comparable with the later experiments, it has been necessary to adopt a standard or base formula to which all the experiments should be reduced. The considerations leading to the adoption of the formula of Francis here used are given below.

In the process of gaging streams at dams the head is usually measured in comparatively still water in an open pond. This condition could not be duplicated in the Cornell experiments. As the formula of James B. Francis is most simple in form for the case of a weir with no velocity of approach, and as it is often convenient to compare the discharge over a dam with that for a thin-edged weir of standard form, a weir formula of the base form used by Francis has been adopted in reducing the experiments. In this formula,

$Q = CLH^{\frac{3}{2}}$.

L = Length of crest corrected for end contractions, if any.

H = Head on weir crest corrected for velocity of approach by the Francis correction formula or an equivalent method.

C = A coefficient determined from experiments on a model dam.

In this connection it may be remarked that the formula of Bazin includes the correction for velocity of approach in the weir coefficient; hence the coefficient for a given weir is comparable only with that for another weir under the same head when the velocity of approach is the same in both cases. Bazin's formula also expresses the velocity of approach implicitly by means of the depth and breadth of the leading channel. In actual gagings the leading channel is often of irregular form, hence it becomes necessary to eliminate the depth and breadth of the channel from the formula.

There is considerable variation in the magnitude of the correction for velocity of approach used by different experimenters. As a rule, the velocity of approach is negligible at gaging stations at dams. It became necessary, therefore, in reducing these experiments to determine from the measured discharge and observed head what the head would have been had the same discharge taken place over a weir in a still pond. To accomplish this the formula for correction for velocity of approach adopted by James B. Francis has been used. This being the case, it is to be noted that in applying the coefficients, which, as given, have been reduced as nearly as possible to the basis of no velocity of approach, the same method of velocity correction must be used, and if it is used no error will result where the actual velocity of approach is nearly the same as that which occurred in the experiments.

BAZIN'S EXPERIMENTS ON WEIRS OF IRREGULAR CROSS SECTION.

These include a wide variety of forms, many of which will seldom be found in America, and the use of which for purposes of gaging would be ill advised.

The small size of the models used, high velocity of approach, and narrow range of heads covered, limit the application of these results. No effort has been made to present all the results in this paper.[a] Certain series, useful for comparison, have been recomputed as described below, and by grouping similar sections we may determine the general effect of various slope and crest modifications.

BAZIN'S CORRECTION FOR VELOCITY OF APPROACH.

The base formula for weir discharge adopted by Bazin and the method of taking into account the velocity of approach are described in connection with his experiments on thin-edged weirs (p. 31).

The following discussion shows the complex character of the Bazin coefficients, and the fact that they do not express directly the relative discharging capacity of weirs of irregular section.

The effect of velocity of approach is to increase the discharge at a given observed head, D, over what it would be if the same head were measured in still water, as in a deep, broad pond.

Bazin's coefficients in the form published are not readily applicable in practice to weirs of other heights, or to weirs in ponds, or otherwise to any but weirs in restricted channels of the depth and width of the weir.

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[a] For complete original data, see Bazin, as translated by Marichal and Trautwine in Proc. Engineers Club Phila., vol. 7, pp. 259-310; vol. 9, pp. 231-244, 287-319; vol. 10, pp. 121-164; also numerous experiments reduced to English units by Rafter and others, Trans. Am. Soc. C. E., vol. 44, pp. 220-398.

The Bazin coefficients as published may be considered as comprising two principal factors. M being the Bazin coefficient, we may write

$M=FC$.

F = velocity of approach effect.

C = contraction effect.

Bazin uses a correction formula for velocity of approach, derived from the expression

$$H=D+1.69\frac{v^2}{2g} \text{ or } D+\alpha h.$$

Consider a standard weir and experimental weir both of the same height, but of different form, the measured depth being the same, and the Bazin coefficients being M and m, the velocity of approach and discharge V and v and Q and q, respectively, and C and C_1 the coefficients in a formula in which the velocity of approach correction is eliminated from the coefficient and applied to the head; then the discharge for the standard weir would be,

using the Bazin coefficients,

$$Q=MLD\sqrt{2gD}=M'D^{\frac{3}{2}},$$

where $M'=M\sqrt{2g}$ and $L=1.0$;

using the coefficient C,

$$Q=CH^{\frac{3}{2}}=C(D+\alpha h)^{\frac{3}{2}},$$

taking roots

$$\left(\frac{C}{M'}\right)^{\frac{2}{3}}=\frac{D}{D+\alpha h}.$$

Bazin does not give the quantities of flow in the tables of results of his experiments, hence to determine h it is necessary to calculate Q, v, and h from the known values M and D and from P, the height of weir.

D being the same for both the standard and the experimental weirs, we have for the experimental weir

$$\left(\frac{C_1}{m}\right)^{\frac{2}{3}}=\frac{D}{D+\alpha h_1},$$

C_1 being the coefficient for the experimental weir, and h_1 the velocity head.

Hence, by multiplication,

$$\left(\frac{m}{M}\right)^{\frac{2}{3}}\left(\frac{C}{C_1}\right)^{\frac{2}{3}}=\frac{D}{D+\alpha h}\times\frac{D+\alpha h_1}{D},$$

and

$$\left(\frac{m}{M}\right)^{\frac{2}{3}}=\left(\frac{C_1}{C}\right)^{\frac{2}{3}}\times\frac{D+\alpha h_1}{D+\alpha h},$$

or

$$\frac{m}{M}=\frac{C_1}{C}\times\left(\frac{D+\alpha h_1}{D+\alpha h}\right)^{\frac{3}{2}}.$$

The velocity of approach for a given depth on a weir is proportional to C, hence, since h is proportional to v^2, we have

$$\frac{h_1}{h}=\left(\frac{C_1}{C}\right)^2.$$

Hence,

$$\frac{m}{M}=\frac{C_1}{C}\left(\frac{D+\left(\frac{C_1}{C}\right)^2\alpha h}{D+\alpha h}\right)^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (57)$$

The ratio $\frac{m}{M}$ used by Bazin is not, therefore, precisely a measure of the relative discharging capacities of the two weirs under similar conditions of head and velocity of approach, for the reason that the velocity of approach will not be the same for both weirs if the Bazin coefficients are different. The ratio m/M is made up of two factors, one of which, C_1/C, expresses the absolute relative discharging capacities of the two weirs under similar conditions of head and velocity of approach, and the other expresses the effect of the change in discharging capacity on the velocity of approach for a given depth on a weir of given height.

Thus the coefficient M for any weir has, by Bazin's method of reduction, different values for every depth and for every height of weir that may occur.

For reasons elsewhere stated it is preferred to express by $\frac{C}{C_1}$ only the relative discharging capacities of the weirs where the velocity of approach is the same in both. It is then practically a measure of the vertical contraction of the nappe, and is constant for a given head for any height of weir, and may be sensibly constant for various depths on the weir.

RECOMPUTATION OF COEFFICIENTS IN BAZIN'S EXPERIMENTS.

In reporting the results of his experiments on weirs of irregular section, Bazin gives the observed heads on the standard weir of comparison, the absolute coefficient m applying for each depth on the experimental weir and the ratio m/M of the experimental and standard weir coefficients.

The results give coefficients which strictly apply only to weirs having both the same form of section and the same heights as those of Bazin. Although weirs of *sectional form* geometrically similar to Bazin's are common, yet few actual weirs have the same height as his. There appear to be two elements which may render inaccurate the application of Bazin's absolute coefficients to weirs of varying height: (1) The difference in velocity of approach; (2) the difference in contraction of the nappe for a higher or lower weir.

In order to render the results of Bazin's experiments comparable one with another and with later experiments, a number of series have been recomputed, the velocity of approach being treated in the same manner as in the computation of experiments at Cornell hydraulic laboratory.

The method is outlined below, the references being to the tables of Bazin's experiments given on pages 68 to 81.

Column 2 gives the observed head reduced to feet for the experimental weir.

Column 4 the absolute coefficient $C_1 = m\sqrt{2g}$.

(These have been reduced from Bazin's original tables.)

Column 5 gives the discharge per foot of crest over the experimental weir calculated by the formula

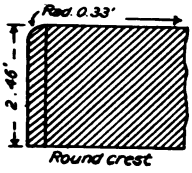
$$Q = mLD\sqrt{2gD} = C_1 LD^{\frac{3}{2}},$$

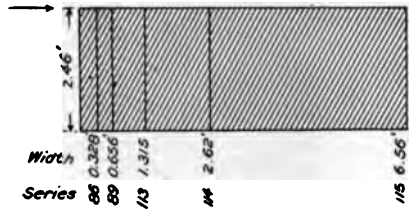
quantities in column 3 being taken directly from a table of three-halves powers.

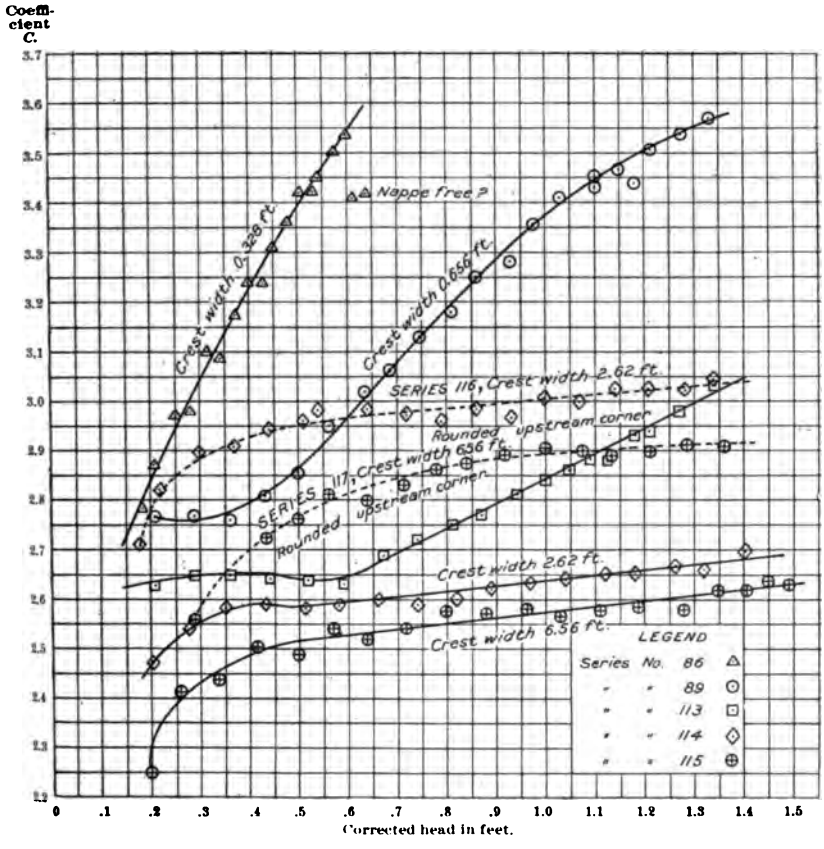
In column 6 the actual velocity of approach, $v = \frac{Q}{P+D}$, is given, and in column 7 the velocity head, $h = \frac{v^2}{2g}$.

The discharge over the standard weir was calculated by Bazin by using his own formula and velocity of approach correction. He does not give the discharge, however, and we have been obliged to work back and obtain it from the data given for the experimental weir.

Having determined the actual discharge and the observed head, we are now at liberty to assume such a law of velocity of approach correction in deducing our new coefficients as we choose. We will therefore deduce the coefficients in such form that when applied to a weir

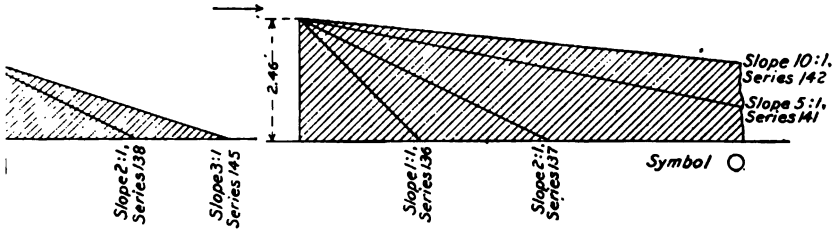


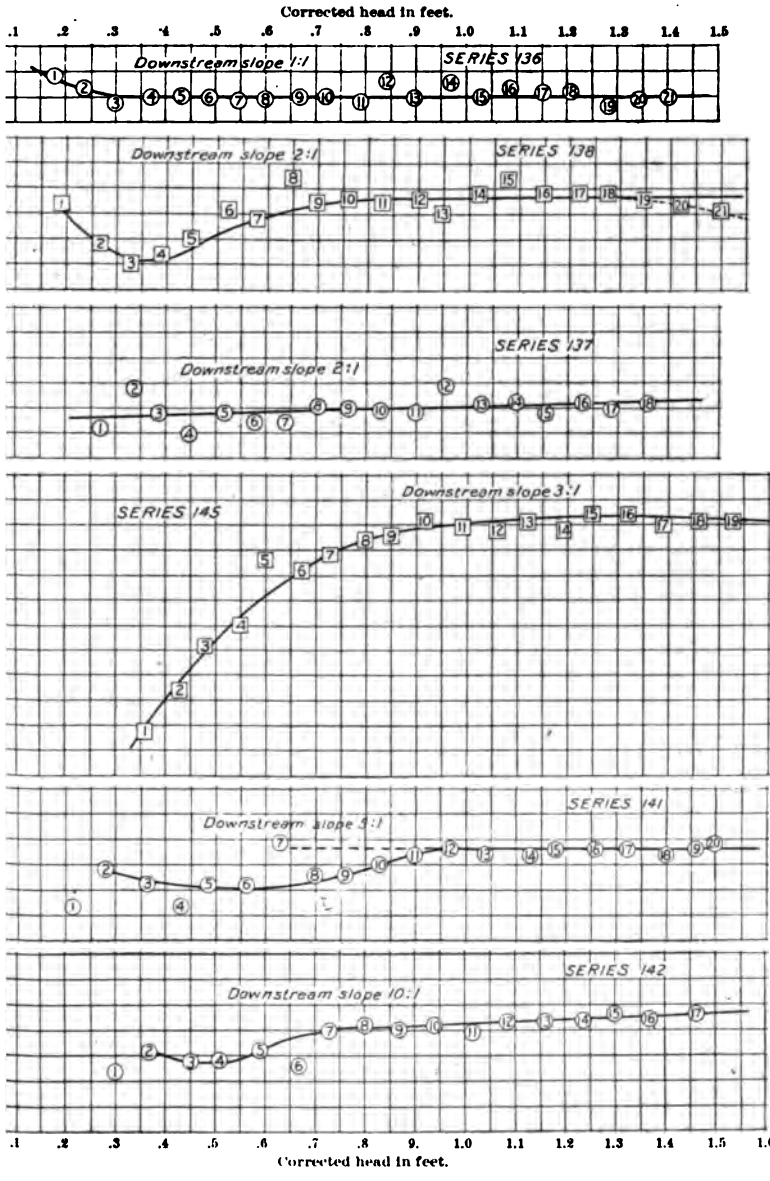




EXPERIMENTS OF BAZIN ON BROAD-CRESTED WEIRS.

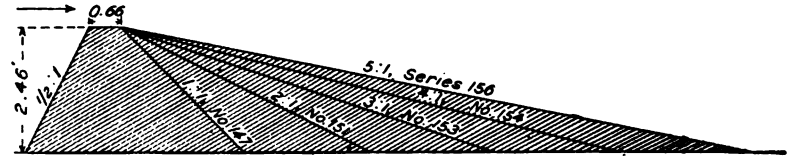
Velocity-of-approach correction by the Francis method.

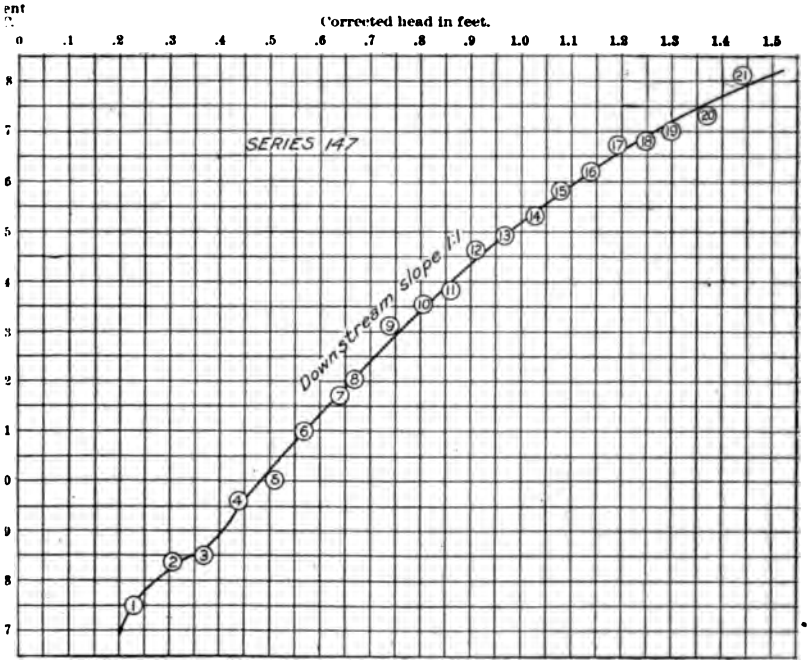


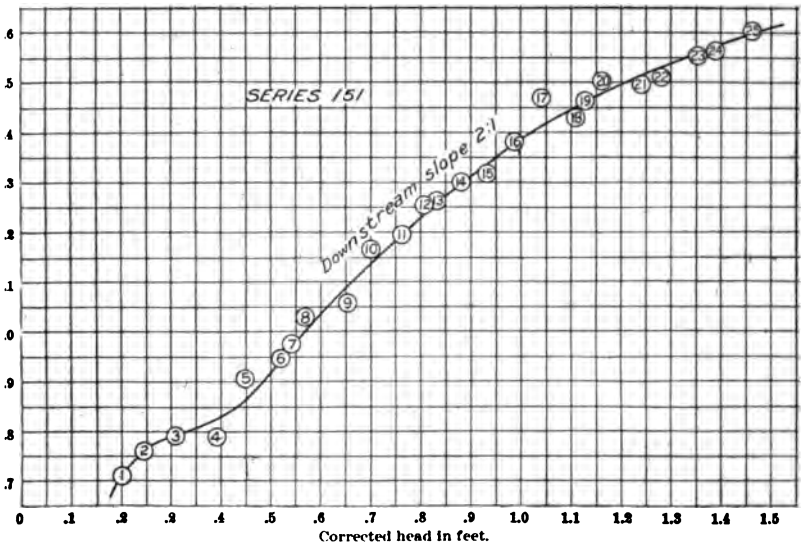


XPERIMENTS OF BAZIN ON WEIRS OF TRIANGULAR SECTION WITH VARYING DOWNSTREAM SLOPE.

Velocity-of-approach correction by the Francis method.

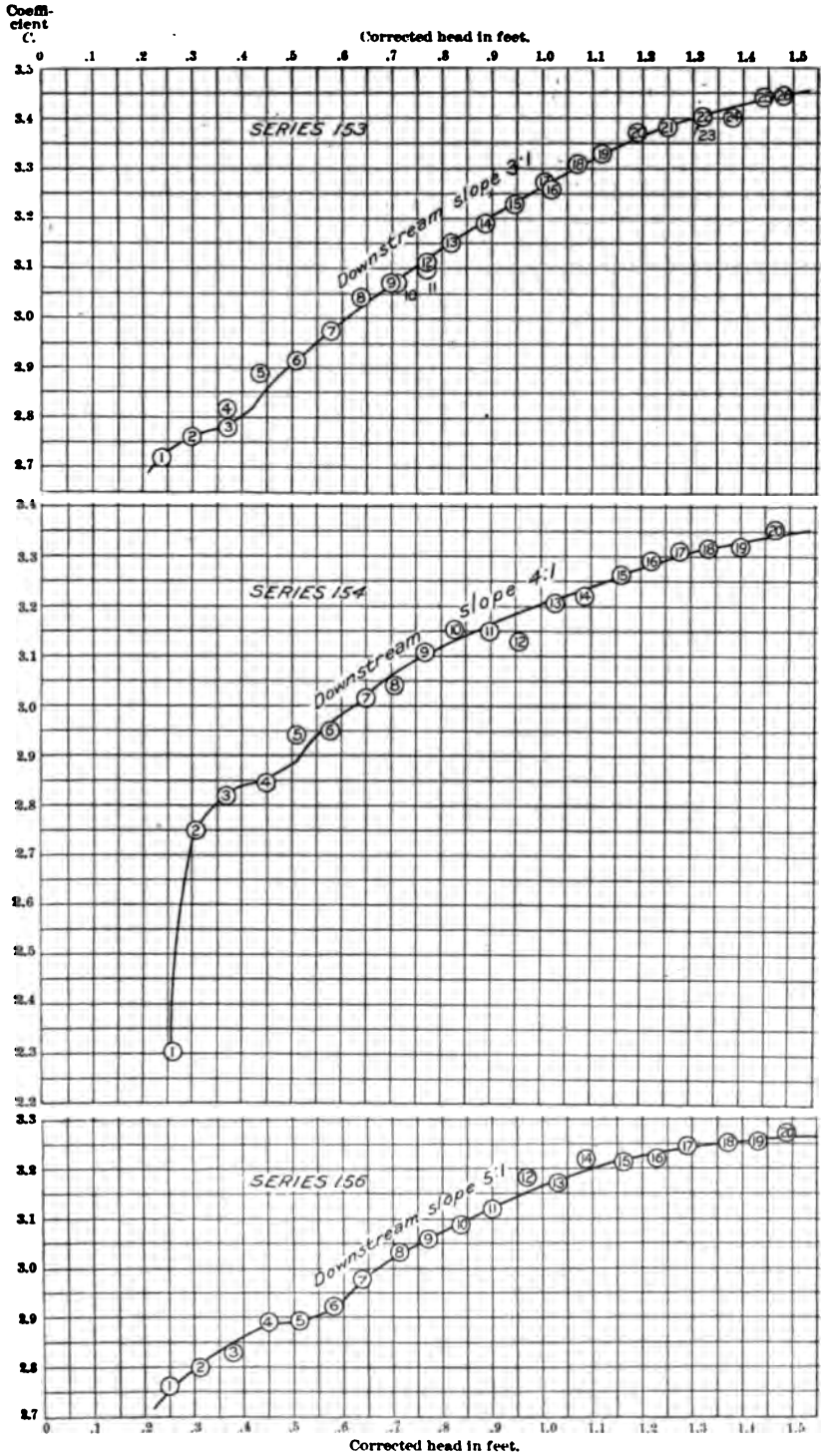






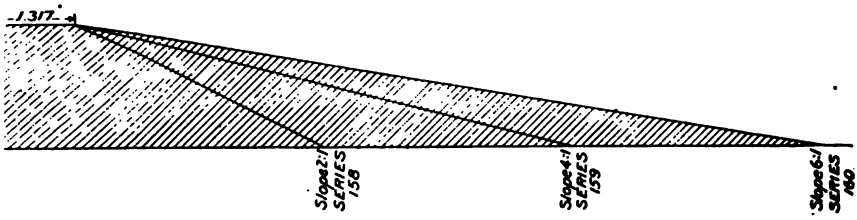
EXPERIMENTS OF BAZIN ON WEIRS OF TRAPEZOIDAL SECTION WITH VARYING DOWNSTREAM SLOPE.

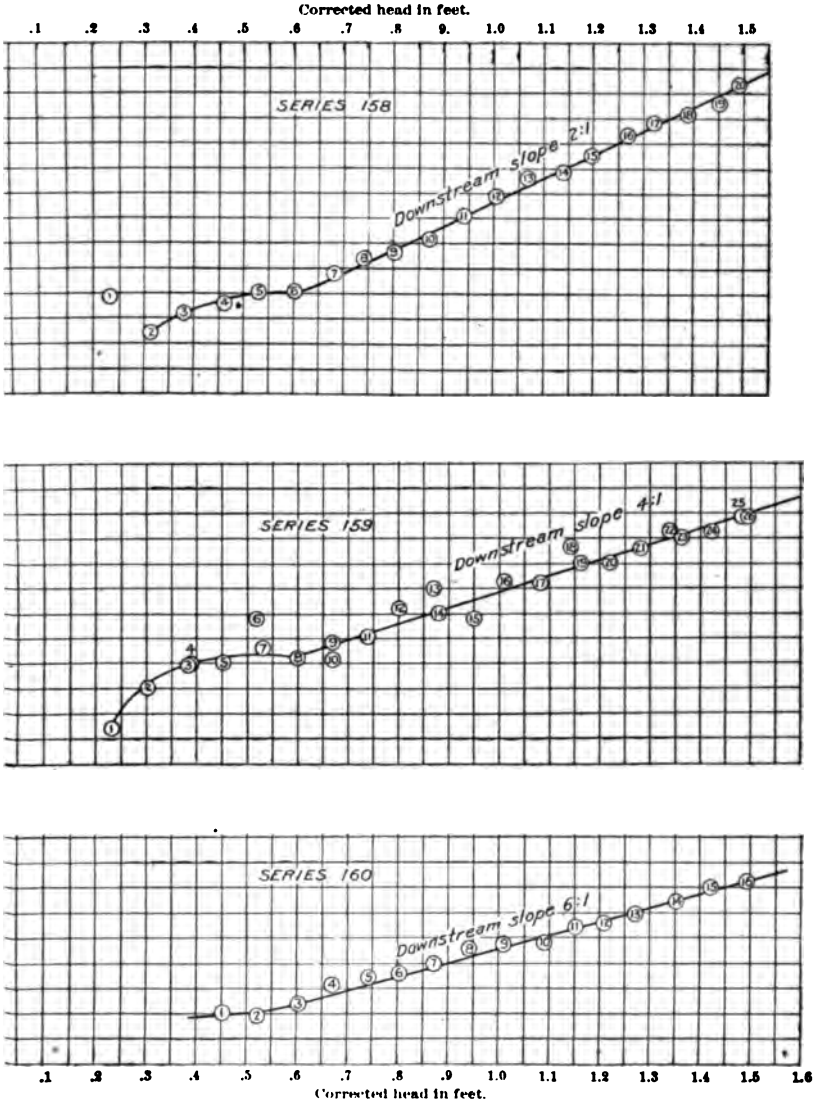
Velocity-of-approach correction by the Francis method. (See also Pl. VII.)



EXPERIMENTS OF BAZIN ON WEIRS OF TRAPEZOIDAL SECTION WITH VARYING DOWNSTREAM SLOPE.

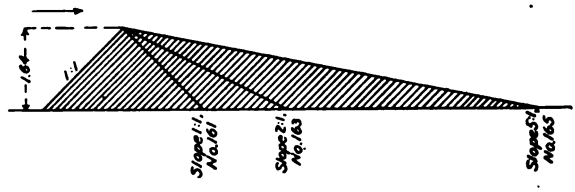
Velocity-of-approach correction by the Francis method. (For cross section see PL. VI.)

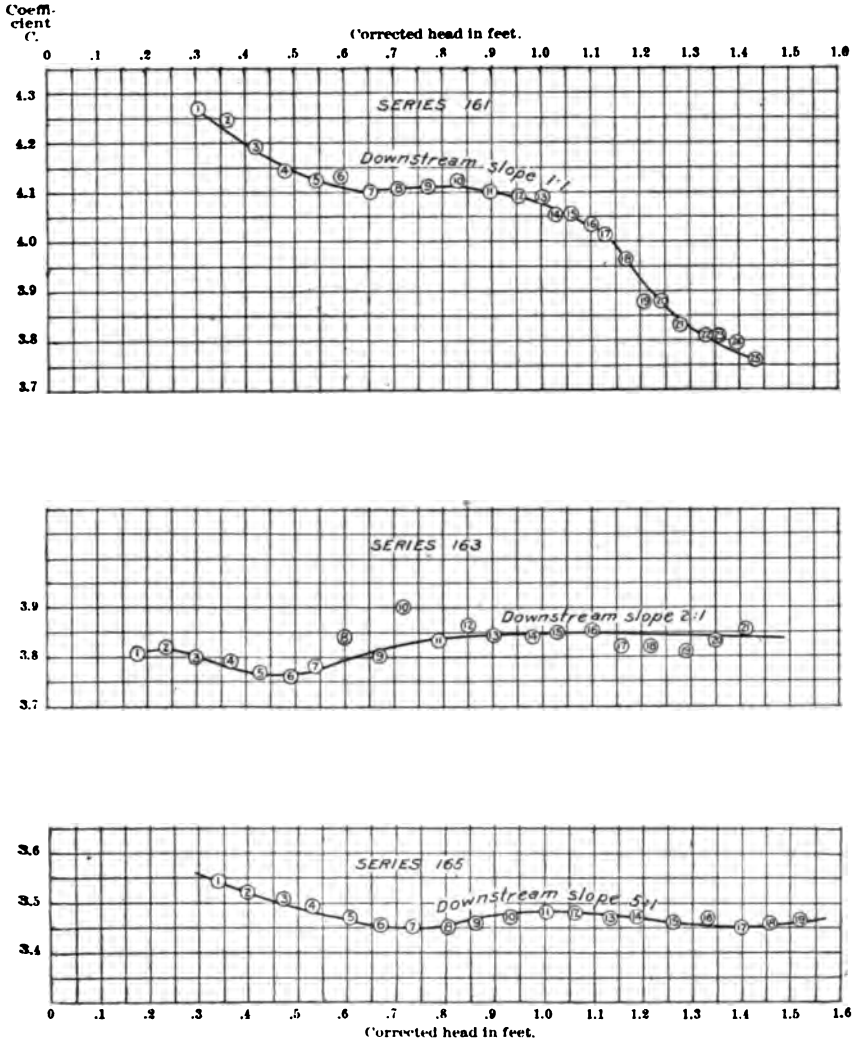




EXPERIMENTS OF BAZIN ON WEIRS OF TRAPEZOIDAL SECTION WITH VARYING DOWNSTREAM SLOPE.

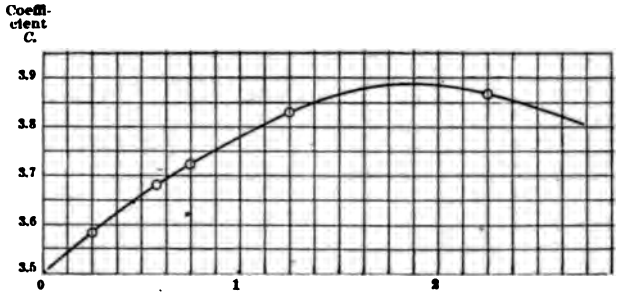
Velocity-of-approach correction by the Francis method.



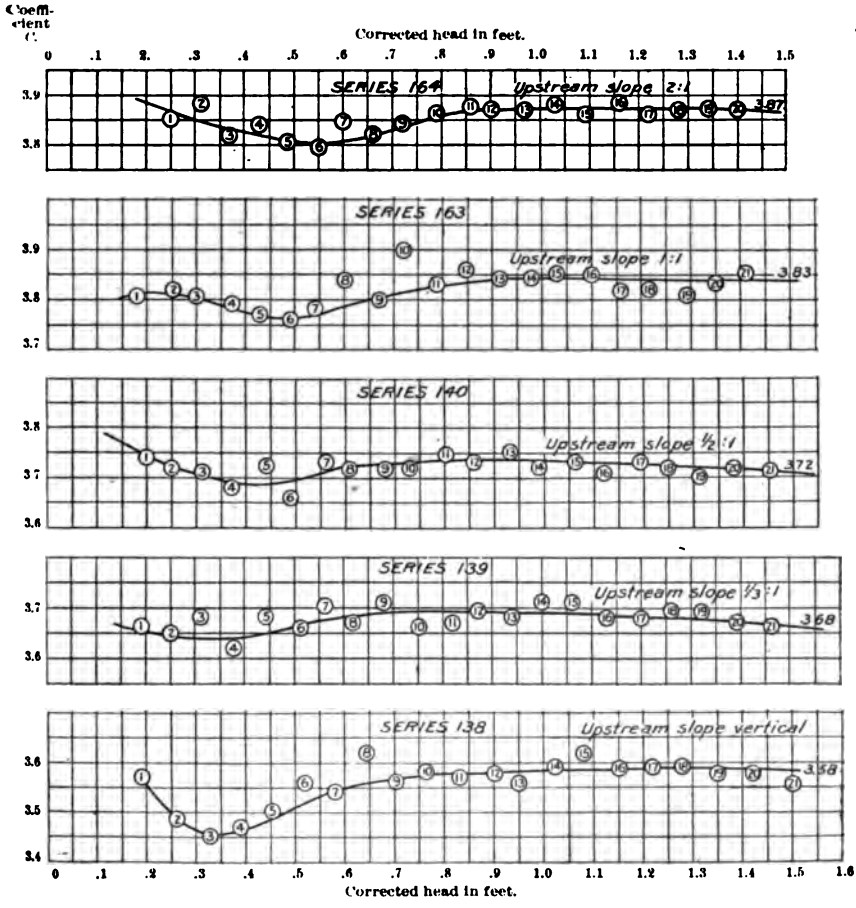


EXPERIMENTS OF BAZIN ON WEIRS OF TRIANGULAR SECTION WITH VARYING DOWNSTREAM SLOPE.

Velocity-of-approach correction by the Francis method.

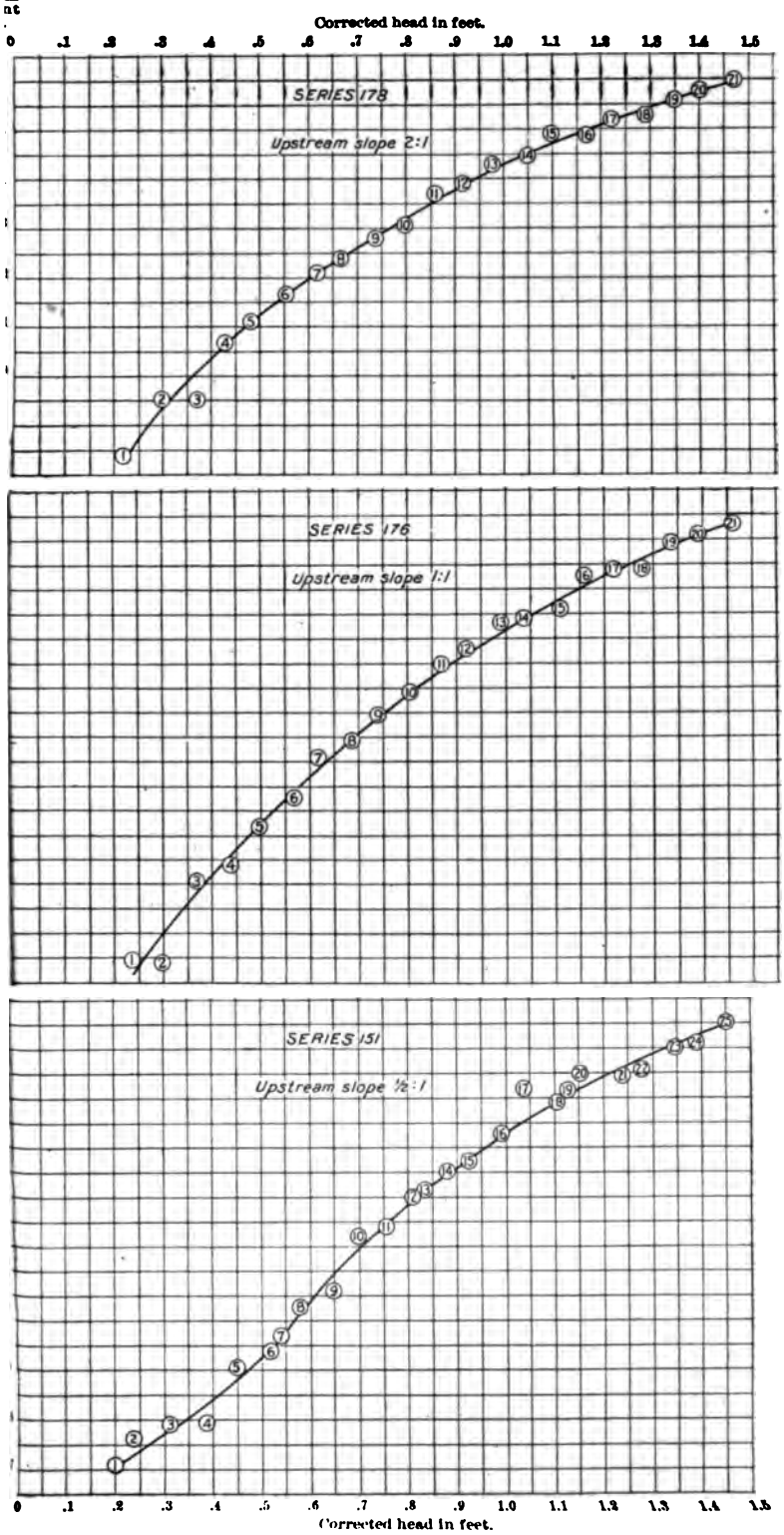


MEAN CONSTANT COEFFICIENTS FOR VARYING SLOPE OF UPSTREAM FACE.

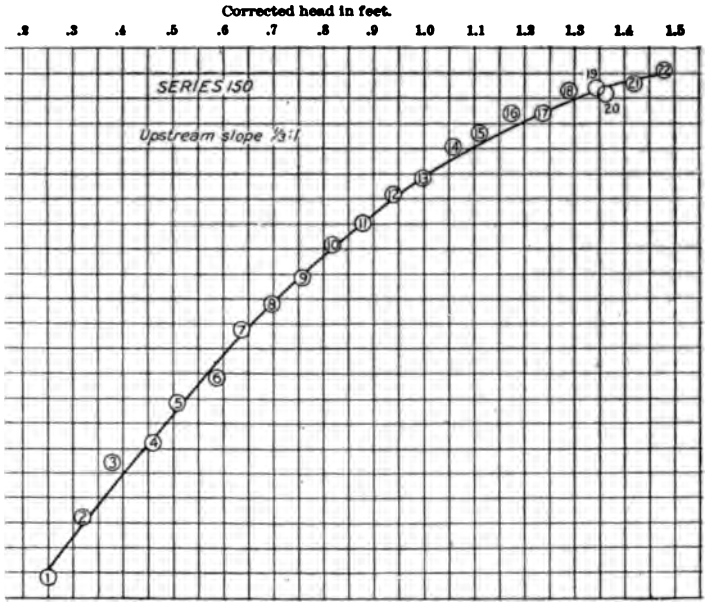


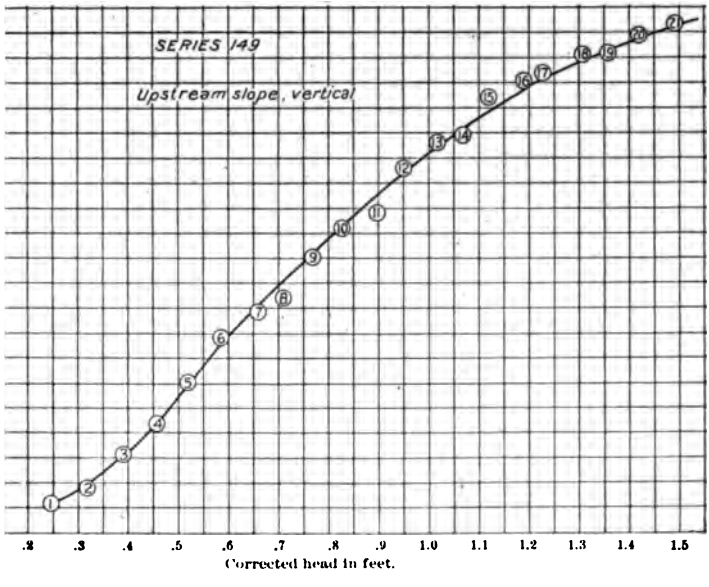
EXPERIMENTS OF BAZIN ON WEIRS OF TRIANGULAR SECTION WITH VARYING UPSTREAM SLOPE.

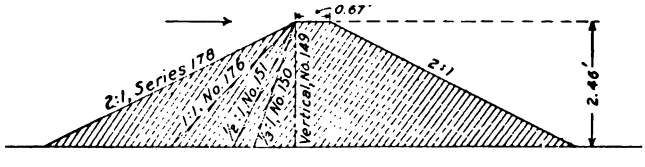
Velocity-of-approach correction by the Francis method.



EXPERIMENTS OF BAZIN ON WEIRS OF TRAPEZOIDAL SECTION WITH VAR
UPSTREAM SLOPE.







MENTS OF BAZIN ON WEIRS OF TRAPEZOIDAL SECTION WITH VARYING UPSTREAM SLOPE.

Velocity-of-approach correction by the Francis method. (See also Pl. XI.)

which there is velocity of approach we may apply the correction mula of Francis,

$$H=\left[(D+h)^{\frac{3}{2}}-h^{\frac{3}{2}}\right]^{\frac{2}{3}}.$$

A sufficient approximation to this formula for our present purposes ıy be obtained if we simply make

$$H=D+\frac{v^2}{2g},$$

ıere v is the velocity of approach corresponding to the trial dis-ırge for the head D, no successive approximations being made, as uld be necessary to determine the true head H by the Francis cor-:tion formula.

For example, in an extreme case, using a thin-edged weir

$$D=1.0, \quad P=1.0, \quad v \text{ (approx.)} \frac{Q}{P+D}=\frac{3.33}{2}=1.665$$

$$h=\frac{v^2}{2g}=0.0431 \quad \text{whence} \quad H=D+\frac{v^2}{2g}=1.0431,$$

l $Q=3.547$.

By the Francis correction formula we find, using three successive proximations,

$$Q_1=3.5183 \text{ giving } v=1.7591$$
$$Q_2=3.5387 \text{ giving } v=1.7694$$
$$Q_3=3.541 \text{ as the final discharge,}$$

at the difference is 0.11 of 1 per cent. We are therefore justified using this method to determine values of C to two places decimals, r to within one-fourth to one-half per cent.

We have also used $\sqrt{2g}=8.02$, as in the reduction of the Cornell xperiments.

Column 8 gives the corrected head,

$$H=D+h.$$

Column 10 gives the final coefficient C deduced by the formula

$$C=\frac{Q}{H^{\frac{3}{2}}}.$$

Pls. IV to XII show the resulting discharge coefficients.

Bazin's experiments on weirs of irregular section.

Bazin's Series, No. 86.
Crest length, 6.55 feet.
Crest height, 2.46 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.1820	0.0777	2.7829	0.2160	0.082	.....	0.1820	0.0777	2.78
2	.2119	.0976	2.8712	.2801	.105	.....	.2119	.0976	2.87
3	.2509	.1257	2.9674	.3733	.138	.....	.2509	.1257	2.97
4	.2781	.1466	2.9754	.4369	.159	.....	.2781	.1466	2.98
5	.3067	.1701	3.0957	.5273	.190	0.0006	.3073	.1701	3.10
6	.3392	.1974	3.0957	.6119	.218	.0008	.3400	.1983	3.09
7	.3678	.2232	3.1839	.7098	.251	.0010	.3688	.2241	3.17
8	.4016	.2549	3.2321	.8233	.288	.0013	.4029	.2539	3.24
9	.4251	.2771	3.2641	.9033	.303	.0014	.4265	.2786	3.24
10	.4527	.3049	3.3283	1.0153	.350	.0019	.4546	.3069	3.31
11	.4770	.3294	3.3844	1.1137	.379	.0022	.4792	.3315	3.36
12	.5075	.3616	3.4406	1.2449	.420	.0027	.5102	.3642	3.42
13	.5360	.3924	3.4807	1.3656	.455	.0033	.5393	.3957	3.45
14	.5639	.4235	3.5368	1.4992	.496	.0039	.5678	.4280	3.50
15	.5973	.4613	3.5930	1.6561	.542	.0045	.6018	.4671	3.54
16	a.5304	.3858	3.4566	1.3349	.446	.0031	.5335	.3897	3.42
17	a.6032	.4683	3.4486	1.6156	.528	.0044	.6076	.4740	3.41
18	a.6347	.5060	3.4646	1.7508	.566	.0051	.6398	.5120	3.42

Bazin's Series, No. 89.
Crest length, 6.55 feet.
Crest height, 2.46 feet.

Cross section.

1	0.2079	0.0948	2.7669	0.2626	0.098	.....	0.2379	0.0948	2.77
2	.2873	.1538	2.7669	.4260	.155	.....	.2873	.1538	2.77
3	.3641	.2196	2.7669	.6083	.216	0.0008	.3649	.2205	2.76
4	.4337	.2859	2.8230	.8062	.279	.0012	.4349	.2869	2.81
5	.4963	.3494	2.8792	1.0063	.340	.0018	.4981	.3515	2.86
6	.5619	.4213	2.9674	1.2513	.414	.0026	.5635	.4235	2.95
7	.6331	.5036	3.0476	1.5360	.498	.0039	.6370	.5084	3.02
8	.6890	.57195	3.0877	1.7673	.560	.0049	.6939	.5782	3.06
9	.7490	.6482	3.1679	2.0548	.640	.0064	.7554	.6561	3.13
10	.7985	.7135	3.2160	2.2975	.705	.0078	.8063	.7236	3.18
11	.8546	.7906	3.2962	2.6090	.785	.0097	.8643	.8031	3.25
12	.9228	.8867	3.3524	2.9704	.879	.0120	.9348	.9041	3.28
13	.9648	.9479	3.4326	3.2513	.949	.0140	.9788	.9687	3.36
14	1.0236	1.0362	3.4887	3.6163	1.038	.0168	1.0404	1.0606	3.41
15	1.0784	1.1193	3.5288	3.9511	1.118	.0195	1.0979	1.1505	3.43
16	1.1312	1.2028	3.5849	4.3060	1.201	.0224	1.1536	1.2396	3.47
17	1.1866	1.2932	3.6331	4.6943	1.292	.0259	1.2125	1.3359	3.51
18	1.2375	1.3767	3.6732	5.0525	1.364	.0288	1.2663	1.4245	3.54
19	1.2959	1.4754	3.7052	5.4737	1.456	.0331	1.3290	1.5321	3.57
20	a 1.0807	1.1239	3.5368	3.9786	1.122	.0195	1.1002	1.1537	3.45
21	a 1.1587	1.2477	3.5448	4.4169	1.219	.0231	1.1818	1.2850	3.44

a Nappe free from the crest.

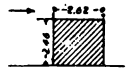
Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 113.
Crest height, 2.463 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.208	0.0948	2.64	0.2503	.....	.....	0.208	0.09484	2.63
2	.289	.1554	2.66	.4134	.....	.....	.289	.1562	2.65
3	.363	.2187	2.66	.5817	0.206	0.0007	.3637	.2196	2.65
4	.443	.2949	2.65	.7815	.269	.0011	.4441	.296	2.64
5	.518	.3728	2.66	.9916	.332	.0017	.5197	.375	2.64
6	.592	.4555	2.64	1.2025	.392	.0024	.5944	.4578	2.63
7	.667	.5447	2.71	1.4761	.472	.0034	.6704	.549	2.69
8	.736	.6314	2.75	1.7364	.542	.0045	.7405	.6377	2.72
9	.805	.7223	2.78	2.0080	.612	.0058	.8108	.7303	2.75
10	.863	.8017	2.80	2.2441	.672	.0070	.8700	.8115	2.77
11	.936	.9056	2.85	2.5810	.758	.0090	.9450	.91865	2.81
12	.989	.9835	2.88	2.8325	.821	.0105	.9995	.9925	2.84
13	1.055	1.0530	2.91	3.0641	.872	.0118	1.0468	1.068	2.86
14	1.076	1.1162	2.94	3.2816	.925	.0132	1.0892	1.1364	2.88
15	1.114	1.1758	2.95	3.4686	.968	.0143	1.1283	1.1980	2.88
16	1.159	1.2478	3.00	3.7434	1.032	.0165	1.1755	1.274	2.93
17	1.197	1.3096	3.01	3.9419	1.075	.0179	1.2149	1.339	2.94
18	1.252	1.4009	3.06	4.2868	1.154	.0206	1.2726	1.436	2.98
19	1.320	1.5166	3.11	4.7166	1.246	.0243	1.3443	1.558	3.03

Bazin's Series, No. 114.
Crest height, 2.46 feet.



Cross section.

1	0.204	0.0921	2.47	0.2275	0.056	.....	0.204	0.0921	2.47
2	.280	.1482	2.54	.3764	.137	.....	.280	.1482	2.54
3	.352	.2089	2.59	.5411	.193	0.0006	.3526	.2097	2.58
4	.433	.28497	2.60	.7409	.256	.0011	.4341	.2860	2.59
5	.504	.3578	2.59	.9267	.313	.0015	.5055	.3594	2.58
6	.578	.4394	2.60	1.1424	.376	.0022	.5802	.4417	2.59
7	.657	.5325	2.62	1.3952	.446	.0031	.6601	.5362	2.60
8	.735	.6302	2.63	1.6511	.517	.0042	.7392	.6353	2.59
9	.810	.7290	2.63	1.9173	.587	.0054	.8154	.7358	2.60
10	.882	.8283	2.65	2.1950	.655	.0068	.8888	.8381	2.62
11	.958	.9377	2.66	2.4913	.728	.0083	.9663	.9494	2.63
12	1.034	1.0514	2.68	2.8178	.806	.0102	1.0442	1.0667	2.64
13	1.112	1.1727	2.69	3.1546	.883	.0120	1.1240	1.1917	2.65
14	1.171	1.2672	2.70	3.4214	.941	.0137	1.1847	1.2899	2.65
15	1.243	1.3858	2.73	3.7832	1.021	.0161	1.2591	1.4127	2.67
16	1.301	1.4839	2.73	4.0510	1.078	.0181	1.3191	1.5149	2.66
17	1.384	1.6282	2.76	4.4938	1.168	.0213	1.4053	1.6654	2.70

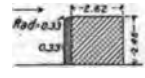
Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 115.
Crest height, 2.46 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.196	0.0868	2.25	0.1953	0.073	.....	0.196	0.0868	2.25
2	.264	.1357	2.41	.3270	.120	.....	.264	.1357	2.41
3	.342	.2001	2.45	.4902	.175	0.0005	.3425	.2005	2.44
4	.415	.2674	2.51	.6712	.233	.0008	.4158	.2683	2.50
5	.495	.3483	2.50	.8708	.290	.0013	.4963	.3494	2.49
6	.566	.4258	2.55	1.0858	.358	.0020	.5680	.4281	2.54
7	.638	.5096	2.54	1.2944	.418	.0027	.6407	.5132	2.52
8	.716	.6059	2.56	1.5511	.487	.0037	.7197	.6109	2.54
9	.792	.7049	2.60	1.8327	.563	.0049	.7969	.7115	2.58
10	.871	.8129	2.60	2.1135	.634	.0062	.8782	.8227	2.57
11	.948	.9230	2.60	2.4098	.706	.0078	.9558	.9347	2.58
12	1.023	1.0347	2.61	2.7006	.775	.0095	1.0325	1.0491	2.57
13	1.097	1.1490	2.63	3.0219	.849	.0112	1.1089	1.1679	2.58
14	1.178	1.2786	2.64	3.3755	.928	.0134	1.1914	1.2997	2.59
15	1.260	1.4144	2.65	3.7482	1.009	.0159	1.276	1.4414	2.58
16	1.330	1.5338	2.68	4.1106	1.085	.0181	1.348	1.5651	2.62
17	1.388	1.6353	2.69	4.3990	1.144	.0202	1.408	1.6707	2.62
18	1.424	1.6993	2.70	4.5881	1.18	.0216	1.446	1.7388	2.64
19	1.467	1.7768	2.70	4.797	1.26	.0247	1.492	1.8225	2.63

Bazin's Series, No. 116.
Crest height, 2.46 feet.



Cross section.

1	0.177	0.0745	2.71	0.2019	0.076	.....	0.177	0.0745	2.71
2	.225	.1068	2.83	.3022	.112	.....	.225	.1068	2.83
3	.296	.1611	2.90	.4672	.169	.....	.296	.1611	2.90
4	.367	.2224	2.92	.6494	.229	0.0008	.3678	.2232	2.91
5	.435	.2870	2.95	.8467	.292	.0013	.4363	.2879	2.94
6	.504	.3578	2.98	1.0662	.360	.0020	.5060	.3599	2.96
7	.537	.3935	2.99	1.1776	.392	.0024	.5394	.3957	2.98
8	.639	.5108	3.01	1.5375	.497	.0039	.6429	.5156	2.98
9	.713	.6021	3.00	1.8063	.569	.0051	.7181	.6084	2.97
10	.781	.6902	3.00	2.0706	.640	.0064	.7874	.6982	2.96
11	.849	.7823	3.02	2.3625	.713	.0078	.8568	.7933	2.98
12	.917	.8781	3.02	2.6519	.793	.0097	.9267	.8925	2.97
13	.986	.9791	3.05	2.9863	.864	.0115	.9975	.9963	3.00
14	1.053	1.0805	3.06	3.3063	.942	.0137	1.0667	1.1021	3.00
15	1.120	1.1853	3.08	3.6507	1.019	.0162	1.1362	1.2108	3.02
16	1.185	1.28995	3.09	3.9859	1.092	.0185	1.2035	1.3203	3.02
17	1.251	1.3992	3.10	4.3375	1.169	.0213	1.2723	1.4346	3.02
18	1.317	1.5114	3.12	4.7156	1.250	.0243	1.3413	1.5529	3.04

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 117.
Crest height, 2.46 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.158	0.06282	2.19	0.1376	0.043	.....	0.158	0.0628	2.19
2	.204	.09212	2.64	.2432	.091	.....	.204	.0921	2.64
3	.289	.1554	2.57	.3994	.145	.....	.289	.1554	2.56
4	.361	.21691	2.65	.5126	.182	0.0005	.3615	.2178	2.35
5	.426	.27808	2.73	.7592	.263	.0011	.4271	.2791	2.72
6	.494	.34724	2.77	.9619	.321	.0016	.4956	.3493	2.76
7	.562	.42134	2.83	1.1924	.395	.0025	.5645	.4247	2.81
8	.635	.5060	2.82	1.4267	.461	.0033	.6383	.5096	2.80
9	.708	.59578	2.86	1.7049	.539	.0045	.7125	.6020	2.83
10	.771	.67702	2.89	1.9566	.606	.0058	.7768	.6849	2.86
11	.834	.76168	2.91	2.2155	.674	.0070	.8410	.7713	2.87
12	.912	.87096	2.93	2.5519	.758	.0090	.9210	.8839	2.89
13	.989	.98352	2.95	2.9014	.841	.0110	1.0000	1.0000	2.90
14	1.064	1.0975	2.95	3.2376	.919	.0132	1.0772	1.1177	2.90
15	1.129	1.1996	2.95	3.5388	.987	.0152	1.1442	1.2236	2.89
16	1.197	1.3096	2.97	3.8895	1.062	.0175	1.2145	1.3392	2.90
17	1.267	1.4262	2.98	4.2501	1.139	.0202	1.2872	1.4601	2.91
18	1.336	1.5442	2.99	4.6172	1.214	.0228	1.3588	1.5842	2.91

Bazin's Series, No. 136.
Crest length, 6.519 feet.
Crest height, 2.46 feet.

Cross section.

1	0.183	0.0783	3.90	0.305	0.12	0.0002	0.1832	0.0783	3.90
2	.244	.1206	3.86	.467	.17	.0004	.2444	.1206	3.87
3	.304	.1676	3.85	.647	.23	.0008	.3048	.1684	3.84
4	.364	.2196	3.86	.849	.30	.0014	.3654	.2206	3.85
5	.424	.2761	3.88	1.071	.37	.0021	.4261	.2781	3.85
6	.484	.3367	3.87	1.304	.44	.0030	.4870	.3399	3.84
7	.542	.3990	3.88	1.548	.52	.0042	.5462	.4035	3.84
8	.597	.4613	3.89	1.793	.59	.0054	.6024	.4671	3.84
9	.658	.5338	3.91	2.088	.67	.0070	.6650	.5423	3.85
10	.713	.6021	3.92	2.360	.74	.0085	.7215	.6135	3.85
11	.776	.6836	3.93	2.684	.83	.0107	.7867	.6982	3.84
12	.830	.7562	3.97	3.001	.91	.0129	.8427	.7740	3.88
13	.887	.8354	3.96	3.300	.99	.0152	.9022	.8567	3.85
14	.953	.9303	3.98	3.701	1.08	.0181	.9711	.9568	3.87
15	1.010	1.0150	3.97	4.029	1.16	.0209	1.0309	1.0468	3.85
16	1.068	1.1037	4.00	4.417	1.25	.0243	1.0923	1.1411	3.87
17	1.122	1.1885	3.99	4.748	1.33	.0275	1.1495	1.2316	3.86
18	1.179	1.2802	4.01	5.133	1.41	.0309	1.2099	1.3310	3.86
19	1.244	1.3875	4.01	5.564	1.50	.0350	1.2790	1.4446	3.85
20	1.299	1.4805	4.01	5.935	1.58	.0388	1.3378	1.5477	3.84
21	1.361	1.5878	4.03	6.408	1.68	.0439	1.4049	1.6654	3.85

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 137.
Crest length, 6.523 feet.
Crest height, 2.46 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.268	0.1388	3.47	0.482	0.18	0.0006	0.2686	0.1395	3.46
2	.332	.1974	3.45	.680	.24	.0009	.3329	.1922	3.54
3	.391	.2445	3.50	.856	.30	.0014	.3924	.2454	3.49
4	.451	.3029	3.47	1.051	.36	.0020	.4530	.3049	3.45
5	.513	.3674	3.53	1.295	.44	.0030	.5160	.3707	3.49
6	.578	.4394	3.51	1.540	.51	.0040	.5820	.4440	3.47
7	.637	.5084	3.51	1.783	.57	.0051	.6421	.5144	3.47
8	.700	.5857	3.55	2.080	.66	.0068	.7068	.5945	3.50
9	.765	.6692	3.56	2.382	.74	.0085	.7735	.6797	3.50
10	.822	.7452	3.56	2.652	.81	.0102	.8322	.7589	3.49
11	.887	.8354	3.56	2.973	.89	.0123	.8993	.8524	3.49
12	.946	.9201	3.62	3.334	.98	.0149	.9609	.9420	3.54
13	1.012	1.0180	3.59	3.662	1.05	.0171	1.0291	1.0438	3.51
14	1.078	1.1193	3.61	4.043	1.14	.0202	1.0982	1.1506	3.51
15	1.142	1.2204	3.60	4.392	1.22	.0231	1.1651	1.2575	3.49
16	1.201	1.3162	3.62	4.778	1.30	.0263	1.2273	1.3591	3.52
17	1.262	1.4178	3.62	5.140	1.38	.0296	1.2916	1.4686	3.50
18	1.322	1.5200	3.64	5.533	1.46	.0331	1.3551	1.5773	3.51

Bazin's Series, No. 138.
Crest length, 6.532 feet.
Crest height, 1.64 feet.

Cross section.

1	0.194	0.0854	3.57	0.305	0.17	0.0004	0.1944	0.0854	3.57
2	.263	.1349	3.50	.473	.25	.0010	.2640	.1357	3.48
3	.327	.1870	3.48	.651	.33	.0017	.3287	.1887	3.45
4	.391	.2445	3.50	.858	.42	.0027	.3937	.2473	3.47
5	.447	.2989	3.56	1.064	.50	.0039	.4519	.3039	3.50
6	.510	.3642	3.63	1.321	.61	.0058	.5158	.3706	3.56
7	.571	.4314	3.62	1.560	.70	.0076	.5786	.4405	3.54
8	.626	.4953	3.71	1.838	.81	.0102	.6362	.5072	3.62
9	.685	.5670	3.66	2.075	.89	.0123	.6973	.5820	3.56
10	.745	.6431	3.69	2.373	.99	.0152	.7602	.6626	3.58
11	.807	.7250	3.70	2.683	1.09	.0185	.8255	.7507	3.57
12	.873	.8157	3.72	3.036	1.21	.0228	.8958	.8481	3.58
13	.927	.8926	3.72	3.318	1.29	.0259	.9529	.9303	3.56
14	.992	.9880	3.76	3.715	1.41	.0309	1.0229	1.0347	3.59
15	1.045	1.0683	3.80	4.060	1.51	.0354	1.0804	1.1224	3.62
16	1.110	1.1695	3.78	4.422	1.61	.0403	1.1503	1.2332	3.58
17	1.176	1.2753	3.79	4.851	1.72	.0460	1.2220	1.3508	3.59
18	1.233	1.3691	3.81	5.220	1.82	.0515	1.2845	1.4550	3.59
19	1.289	1.4645	3.82	5.577	1.90	.0561	1.3451	1.5599	3.58
20	1.355	1.5773	3.82	6.036	2.01	.0628	1.4178	1.6885	3.57
21	1.429	1.7082	3.83	6.542	2.13	.0705	1.4995	1.8362	3.56

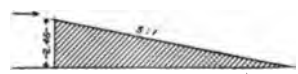
Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 145.
Crest length, 6.541 feet.
Crest height, 1.64 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.359	0.2151	3.02	0.649	0.32	0.0016	0.3606	0.2169	2.99
2	.424	.2761	3.10	.856	.42	.0027	.4267	.2790	3.07
3	.479	.3315	3.18	1.053	.50	.0039	.4869	.3335	3.16
4	.547	.4046	3.25	1.316	.60	.0056	.5526	.4112	3.20
5	.592	.4636	3.35	1.553	.69	.0074	.5994	.4636	3.33
6	.658	.5838	3.38	1.805	.78	.0095	.6675	.5447	3.31
7	.720	.6109	3.42	2.090	.89	.0123	.7323	.6263	3.34
8	.781	.6902	3.47	2.394	.99	.0152	.7962	.7102	3.37
9	.835	.7631	3.49	2.663	1.07	.0178	.8528	.7878	3.38
10	.902	.8567	3.53	3.025	1.19	.0220	.9240	.8882	3.41
11	.962	.9435	3.53	3.332	1.28	.0255	.9875	.9806	3.40
12	1.032	1.0484	3.53	3.707	1.39	.0300	1.0620	1.0944	3.39
13	1.087	1.1333	3.58	4.045	1.48	.0341	1.1211	1.1869	3.41
14	1.152	1.2364	3.58	4.403	1.58	.0388	1.1908	1.2997	3.39
15	1.210	1.3310	3.61	4.801	1.68	.0439	1.2539	1.4042	3.42
16	1.274	1.4380	3.61	5.198	1.78	.0493	1.3233	1.5218	3.42
17	1.334	1.5408	3.62	5.575	1.88	.0549	1.3889	1.6370	3.40
18	1.396	1.6494	3.64	6.006	1.98	.0609	1.4569	1.7586	3.42
19	1.467	1.7768	3.64	6.479	2.09	.0679	1.5349	1.9016	3.41

Bazin's Series, No. 141.
Crest length, 6.520 feet.
Crest height, 2.46 feet.



Cross section.

1	0.215	0.0997	3.02	0.301	0.11	0.0002	0.2152	0.0997	3.02
2	.281	.1490	3.09	.460	.17	.0004	.2814	.1490	3.09
3	.355	.2116	3.07	.650	.24	.0009	.3559	.2124	3.06
4	.425	.2771	3.04	.842	.29	.0013	.4263	.2781	3.02
5	.489	.3420	3.08	1.053	.37	.0021	.4911	.3441	3.06
6	.561	.4202	3.08	1.294	.43	.0029	.5639	.4235	3.06
7	.624	.4929	3.17	1.562	.51	.0040	.6280	.4976	3.14
8	.692	.5757	3.11	1.791	.57	.0051	.6971	.5820	3.08
9	.758	.6600	3.12	2.059	.64	.0064	.7644	.6678	3.08
10	.822	.7452	3.15	2.347	.72	.0081	.8301	.7562	3.10
11	.888	.8368	3.17	2.653	.79	.0097	.8977	.8509	3.12
12	.956	.9347	3.19	2.983	.87	.0118	.9678	.9523	3.13
13	1.029	1.0438	3.17	3.309	.95	.0140	1.0430	1.0652	3.12
14	1.113	1.1742	3.20	3.757	1.04	.0168	1.1298	1.2012	3.13
15	1.165	1.2575	3.21	4.045	1.12	.0195	1.1845	1.2884	3.14
16	1.237	1.3758	3.20	4.416	1.19	.0220	1.2590	1.4127	3.13
17	1.298	1.4788	3.22	4.706	1.27	.0251	1.3231	1.5218	3.13
18	1.369	1.6018	3.22	5.152	1.34	.0279	1.3969	1.6511	3.12
19	1.431	1.7118	3.24	5.540	1.42	.0313	1.4623	1.7677	3.13
20	1.463	1.7696	3.25	5.752	1.47	.0336	1.4966	1.8307	3.14

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 142.
Crest length, 6.523 feet.
Crest height, 2.46 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.300	0.1643	2.83	0.464	0.17	0.0004	0.3004	0.1643	2.82
2	.369	.2242	2.87	.643	.23	.0008	.3698	.2251	2.86
3	.447	.2989	2.87	.851	.29	.0013	.4483	.2999	2.84
4	.509	.3631	2.86	1.038	.35	.0019	.5109	.3652	2.84
5	.591	.4544	2.88	1.308	.43	.0029	.5939	.4578	2.86
6	.656	.5435	2.86	1.554	.50	.0039	.6699	.5484	2.83
7	.727	.6199	2.92	1.810	.57	.0051	.7327	.6263	2.89
8	.795	.7089	2.94	2.084	.64	.0064	.8014	.7155	2.91
9	.861	.7989	2.94	2.349	.71	.0078	.8688	.8101	2.90
10	.934	.9027	2.95	2.664	.78	.0095	.9435	.9158	2.91
11	1.007	1.0105	2.95	2.980	.86	.0115	1.0185	1.0286	2.89
12	1.079	1.1208	2.98	3.338	.94	.0137	1.0927	1.1427	2.92
13	1.149	1.2316	2.98	3.665	1.01	.0159	1.1649	1.2575	2.92
14	1.222	1.3508	2.99	4.037	1.10	.0188	1.2408	1.3824	2.92
15	1.285	1.4567	3.00	4.370	1.17	.0213	1.3063	1.4925	2.93
16	1.362	1.5895	3.00	4.770	1.25	.0243	1.3863	1.6317	2.92
17	1.430	1.7100	3.01	5.147	1.30	.0263	1.4563	1.7569	2.93

Bazin's Series, No. 139.
Crest length, 6.532 feet.
Crest height, 1.64 feet.

Cross section.

1	0.190	0.0828	3.66	0.303	0.17	0.0004	0.1904	0.0828	3.66
2	.253	.1273	3.68	.467	.25	.0010	.2540	.1280	3.65
3	.312	.1743	3.72	.647	.33	.0017	.3137	.1759	3.68
4	.375	.2297	3.66	.841	.42	.0027	.3777	.2323	3.62
5	.434	.2860	3.73	1.067	.52	.0042	.4382	.2899	3.68
6	.500	.3536	3.72	1.317	.62	.0060	.5060	.3600	3.66
7	.552	.4101	3.78	1.550	.71	.0078	.5598	.4191	3.70
8	.615	.4823	3.76	1.812	.80	.0099	.6249	.4941	3.67
9	.667	.5447	3.82	2.081	.90	.0126	.6796	.5607	3.71
10	.733	.6276	3.79	2.380	1.00	.0155	.7485	.6482	3.67
11	.798	.7128	3.80	2.709	1.11	.0192	.8172	.7385	3.67
12	.852	.7865	3.84	3.022	1.21	.0228	.8748	.8185	3.69
13	.915	.8753	3.86	3.378	1.32	.0271	.9421	.9143	3.68
14	.969	.9538	3.87	3.692	1.41	.0309	.9961	.9940	3.71
15	1.023	1.0347	3.92	4.038	1.52	.0359	1.0589	1.0897	3.71
16	1.092	1.1411	3.90	4.446	1.63	.0413	1.1333	1.2060	3.68
17	1.151	1.2348	3.90	4.816	1.72	.0460	1.1970	1.3096	3.68
18	1.210	1.3310	3.94	5.240	1.84	.0526	1.2626	1.4194	3.69
19	1.258	1.4110	3.95	5.570	1.92	.0573	1.3153	1.5080	3.69
20	1.326	1.5269	3.93	6.013	2.03	.0641	1.3901	1.6388	3.67
21	1.394	1.6459	3.93	6.484	2.13	.0705	1.4645	1.7714	3.66

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 140.
Crest length, 6.582 feet.
Crest height, 1.64 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.192	0.0835	3.77	0.315	0.17	0.0004	0.1924	0.0841	3.74
2	.252	.1265	3.74	.473	.25	.0010	.2530	.1273	3.72
3	.308	.1709	3.75	.641	.33	.0017	.3097	.1726	3.71
4	.371	.2260	3.71	.838	.42	.0027	.3727	.2278	3.68
5	.436	.2879	3.77	1.086	.52	.0042	.4402	.2919	3.72
6	.488	.3399	3.74	1.276	.60	.0056	.4936	.3472	3.66
7	.549	.4068	3.81	1.551	.71	.0078	.5568	.4157	3.73
8	.604	.4694	3.82	1.792	.80	.0099	.6139	.4811	3.72
9	.664	.5411	3.83	2.072	.90	.0126	.6766	.5570	3.72
10	.719	.6096	3.84	2.342	.99	.0152	.7342	.6289	3.72
11	.785	.6956	3.88	2.700	1.11	.0192	.8042	.7209	3.74
12	.837	.7658	3.88	2.968	1.20	.0224	.8594	.7961	3.73
13	.905	.8610	3.92	3.375	1.32	.0271	.9321	.8998	3.75
14	.961	.9421	3.90	3.674	1.41	.0309	.9919	.9680	3.72
15	1.023	1.0347	3.95	4.069	1.53	.0364	1.0594	1.0898	3.73
16	1.080	1.1224	3.93	4.402	1.62	.0408	1.1208	1.1869	3.71
17	1.143	1.2220	3.97	4.843	1.74	.0471	1.1901	1.2981	3.73
18	1.195	1.3063	3.96	5.187	1.83	.0521	1.2471	1.3925	3.72
19	1.254	1.4043	3.97	5.558	1.92	.0573	1.3113	1.5011	3.70
20	1.316	1.5097	3.99	6.024	2.03	.0641	1.3801	1.6211	3.72
21	1.375	1.6123	4.01	6.456	2.14	.0712	1.4462	1.7388	3.71

Bazin's Series, No. 147.
Crest length, 6.536 feet.
Crest height, 2.46 feet.

Cross section.

1	0.231	0.1110	2.75	0.305	0.11	0.0002	0.2312	0.1110	2.75
2	.308	.1709	2.85	.485	.18	.0005	.3085	.1709	2.84
3	.373	.2278	2.86	.652	.23	.0008	.3738	.2287	2.85
4	.438	.2899	2.97	.861	.30	.0014	.4394	.2909	2.96
5	.503	.3568	3.02	1.078	.37	.0021	.5051	.3589	3.00
6	.569	.4292	3.13	1.343	.44	.0030	.5720	.4326	3.10
7	.637	.5084	3.20	1.626	.54	.0045	.6415	.5132	3.17
8	.681	.5620	3.24	1.821	.58	.0052	.6862	.5682	3.20
9	.734	.6289	3.34	2.109	.66	.0068	.7408	.6378	3.31
10	.797	.7115	3.40	2.417	.74	.0083	.8053	.7223	3.35
11	.845	.7768	3.44	2.673	.81	.0102	.8552	.7906	3.38
12	.898	.8510	3.53	3.004	.89	.0123	.9103	.8681	3.46
13	.953	.9303	3.57	3.320	.97	.0146	.9676	.9523	3.49
14	1.015	1.0226	3.63	3.703	1.06	.0175	1.0325	1.0484	3.53
15	1.063	1.0960	3.67	4.037	1.15	.0206	1.0836	1.1286	3.58
16	1.115	1.1774	3.73	4.401	1.22	.0231	1.1381	1.2140	3.62
17	1.165	1.2575	3.79	4.775	1.31	.0267	1.1917	1.3013	3.67
18	1.217	1.3426	3.83	5.132	1.40	.0305	1.2475	1.3925	3.68
19	1.265	1.4228	3.85	5.467	1.47	.0336	1.2986	1.4805	3.70
20	1.332	1.5373	3.89	5.991	1.58	.0388	1.3708	1.6053	3.73
21	1.394	1.6159	3.98	6.567	1.68	.0439	1.4379	1.7244	3.81

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 149.
Crest length, 6.518 feet.
Crest height, 2.46 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.248	0.1235	2.55	0.316	0.12	0.0002	0.2482	0.1235	2.56
2	.317	.1785	2.58	.462	.17	.0004	.3174	.1785	2.59
3	.390	.2436	2.67	.651	.23	.0008	.3908	.2445	2.66
4	.455	.3070	2.73	.838	.29	.0013	.4563	.3080	2.72
5	.521	.3761	2.82	1.060	.36	.0020	.5230	.3782	2.80
6	.585	.4475	2.89	1.295	.43	.0030	.5850	.4475	2.89
7	.653	.5277	2.97	1.568	.51	.0040	.6570	.5325	2.94
8	.705	.5920	3.00	1.776	.56	.0049	.7099	.5983	2.97
9	.766	.6705	3.08	2.067	.64	.0064	.7724	.6783	3.05
10	.818	.7398	3.16	2.338	.71	.0078	.8258	.7507	3.11
11	.882	.8283	3.23	2.674	.80	.0099	.8979	.8509	3.14
12	.942	.9143	3.30	3.016	.89	.0123	.9543	.9318	3.23
13	.999	.9985	3.36	3.356	.97	.0146	1.0156	1.0241	3.28
14	1.051	1.0774	3.39	3.627	1.03	.0165	1.0665	1.1006	3.30
15	1.103	1.1584	3.45	4.002	1.12	.0195	1.1225	1.1885	3.37
16	1.165	1.2575	3.49	4.397	1.20	.0224	1.1874	1.2932	3.40
17	1.209	1.3294	3.52	4.682	1.27	.0251	1.2341	1.3708	3.42
18	1.281	1.4499	3.57	5.177	1.38	.0296	1.3106	1.5011	3.45
19	1.330	1.5338	3.60	5.508	1.45	.0327	1.3627	1.5912	3.46
20	1.385	1.6300	3.63	5.917	1.54	.0369	1.4219	1.6956	3.49
21	1.446	1.7388	3.67	6.386	1.64	.0418	1.4878	1.8151	3.52

Bazin's Series, No. 150.
Crest length, 6.518 feet.
Crest height, 2.46 feet.

Cross section.

1	0.248	0.1235	2.53	0.314	0.12	0.0002	0.2482	0.1235	2.54
2	.323	.1836	2.65	.488	.16	.0004	.3234	.1836	2.66
3	.379	.2333	2.78	.648	.23	.0008	.3798	.2342	2.77
4	.459	.3110	2.82	.877	.30	.0014	.4604	.3120	2.81
5	.512	.3664	2.91	1.065	.36	.0020	.5140	.3685	2.89
6	.586	.4486	2.96	1.329	.43	.0029	.5889	.4521	2.94
7	.637	.5084	3.07	1.560	.50	.0039	.6409	.5132	3.04
8	.698	.5832	3.12	1.819	.57	.0051	.7031	.5895	3.09
9	.751	.6508	3.18	2.070	.64	.0064	.7574	.6587	3.14
10	.814	.7344	3.26	2.393	.73	.0083	.8223	.7452	3.21
11	.869	.8101	3.31	2.681	.80	.0099	.8789	.8241	3.25
12	.928	.8940	3.37	3.013	.89	.0123	.9403	.9114	3.31
13	.982	.9732	3.42	3.328	.97	.0146	.9966	.9955	3.34
14	1.043	1.0652	3.47	3.713	1.06	.0175	1.0605	1.0913	3.40
15	1.095	1.1459	3.51	4.037	1.13	.0199	1.1149	1.1774	3.43
16	1.152	1.2364	3.56	4.414	1.22	.0231	1.1751	1.2737	3.46
17	1.215	1.3393	3.58	4.797	1.30	.0263	1.2413	1.3825	3.47
18	1.259	1.4127	3.63	5.118	1.38	.0296	1.2856	1.4584	3.51
19	1.315	1.5080	3.65	5.512	1.46	.0331	1.3481	1.5651	3.52
20	1.323	1.5218	[illegible]	5.548	1.47	.0336	1.3566	1.5807	3.51
21	1.380	1.6[illegible]		[illegible]62	1.55	.0374	1.4174	1.6868	3.54
22	1.439	[illegible]		[illegible]	1.64	.0418	1.4808	1.8023	3.56

Bazin's experiments on weirs of irregular section—Continued.

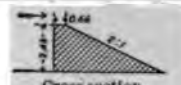
Bazin's Series, No. 151.
Crest length, 6.550 feet.
Crest height, 2.46 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.201	0.0901	2.71	0.244	0.09	0.0001	0.2011	0.0901	2.71
2	.240	.1176	2.81	.329	.12	.0002	.2422	.1191	2.76
3	.307	.1701	2.79	.474	.17	.0004	.3074	.1701	2.79
4	.391	.2445	2.79	.684	.24	.0009	.3919	.2454	2.79
5	.445	.2969	2.92	.867	.30	.0014	.4464	.2979	2.91
6	.514	.3685	2.95	1.089	.37	.0021	.5161	.3707	2.94
7	.537	.3935	2.98	1.174	.39	.0024	.5394	.3957	2.97
8	.573	.4337	3.05	1.324	.43	.0030	.5760	.4371	3.03
9	.643	.5156	3.09	1.594	.51	.0040	.6470	.5204	3.06
10	.695	.5795	3.20	1.856	.59	.0054	.7004	.5857	3.17
11	.756	.6574	3.24	2.129	.66	.0068	.7628	.6665	3.19
12	.800	.7155	3.30	2.362	.72	.0081	.8081	.7263	3.25
13	.826	.7507	3.31	2.486	.76	.0090	.8350	.7631	3.26
14	.867	.8073	3.36	2.712	.81	.0102	.8772	.8213	3.30
15	.921	.8839	3.39	2.997	.89	.0123	.9333	.9013	3.32
16	.975	.9628	3.46	3.332	.97	.0146	.9896	.9850	3.38
17	1.027	1.0408	3.51	3.658	1.04	.0168	1.0438	1.0667	3.47
18	1.090	1.1380	3.52	4.013	1.13	.0199	1.1099	1.1695	3.43
19	1.112	1.1727	3.57	4.177	1.17	.0213	1.1333	1.2060	3.46
20	1.140	1.2172	3.60	4.382	1.22	.0231	1.1631	1.2543	3.50
21	1.209	1.3294	3.61	4.801	1.31	.0267	1.2357	1.3741	3.49
22	1.248	1.3942	3.64	5.060	1.36	.0288	1.2768	1.4431	3.51
23	1.314	1.5063	3.68	5.557	1.47	.0336	1.3476	1.5651	3.55
24	1.352	1.5721	3.71	6.825	1.52	0359	1.3879	1.6352	3.56
25	1.416	1.6850	3.75	6.337	1.64	.0418	1.4578	1.7604	3.60

Bazin's experiments on weirs of irregular section—Continued.

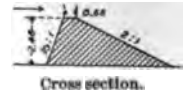
Bazin's Series, No. 149.
Crest length, 6.518 feet.
Crest height, 2.46 feet.



Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.248	0.1235	2.55	0.316	0.12	0.0002	0.2482	0.1235	2.56
2	.317	.1785	2.58	.462	.17	.0004	.3174	.1785	2.59
3	.390	.2436	2.67	.651	.23	.0008	.3908	.2445	2.66
4	.455	.3070	2.73	.838	.29	.0013	.4563	.3080	2.72
5	.521	.3761	2.82	1.060	.36	.0020	.5230	.3782	2.80
6	.585	.4475	2.89	1.295	.43	.0030	.5850	.4475	2.89
7	.653	.5277	2.97	1.568	.51	.0040	.6570	.5325	2.94
8	.705	.5920	3.00	1.776	.56	.0049	.7099	.5983	2.97
9	.766	.6705	3.08	2.067	.64	.0064	.7724	.6783	3.05
10	.818	.7398	3.16	2.338	.71	.0078	.8258	.7507	3.11
11	.882	.8283	3.23	2.674	.80	.0099	.8979	.8509	3.14
12	.942	.9143	3.30	3.016	.89	.0123	.9543	.9318	3.23
13	.999	.9985	3.36	3.356	.97	.0146	1.0156	1.0241	3.28
14	1.051	1.0774	3.39	3.627	1.03	.0165	1.0665	1.1006	3.30
15	1.103	1.1584	3.45	4.002	1.12	.0195	1.1225	1.1885	3.37
16	1.165	1.2575	3.49	4.397	1.20	.0224	1.1874	1.2932	3.40
17	1.209	1.3294	3.52	4.682	1.27	.0251	1.2341	1.3708	3.42
18	1.281	1.4499	3.57	5.177	1.38	.0296	1.3106	1.5011	3.45
19	1.330	1.5338	3.60	5.508	1.45	.0327	1.3627	1.5912	3.46
20	1.385	1.6300	3.63	5.917	1.54	.0369	1.4219	1.6956	3.49
21	1.446	1.7388	3.67	6.386	1.64	.0418	1.4878	1.8151	3.52

Bazin's Series, No. 150.
Crest length, 6.518 feet.
Crest height, 2.46 feet.

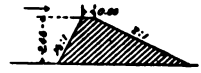


Cross section.

1	0.248	0.1235	2.53	0.314	0.12	0.0002	0.2482	0.1235	2.54
2	.323	.1836	2.65	.488	.16	.0004	.3234	.1836	2.66
3	.379	.2333	2.78	.648	.23	.0008	.3798	.2342	2.77
4	.459	.3110	2.82	.877	.30	.0014	.4604	.3120	2.81
5	.512	.3664	2.91	1.065	.36	.0020	.5140	.3685	2.89
6	.586	.4486	2.96	1.329	.43	.0029	.5889	.4521	2.94
7	.637	.5084	3.07	1.560	.50	.0039	.6409	.5132	3.04
8	.698	.5832	3.12	1.819	.57	.0051	.7031	.5895	3.09
9	.751	.6508	3.18	2.070	.64	.0064	.7574	.6587	3.14
10	.814	.7344	3.26	2.393	.73	.0083	.8223	.7452	3.21
11	.869	.8101	3.31	2.681	.80	.0099	.8789	.8241	3.25
12	.928	.8940	3.37	3.013	.89	.0123	.9403	.9114	3.31
13	.982	.9732	3.42	3.328	.97	.0146	.9966	.9955	3.34
14	1.043	1.0652	3.47	3.713	1.06	.0175	1.0605	1.0913	3.40
15	1.095	1.1459	3.51	4.037	1.13	.0199	1.1149	1.1774	3.43
16	1.152	1.2364	3.56	4.414	1.22	.0231	1.1751	1.2737	3.46
17	1.215	1.3393	3.58	4.797	1.30	.0263	1.2413	1.3825	3.47
18	1.259	1.4127	3.63	5.118	1.38	.0296	1.2856	1.4584	3.51
19	1.315	1.5080	3.65	5.512	1.46	.0333	1.3481	1.5651	3.52
20	1.323	1.5218	3.65	5.548	1.47	.0336	1.3566	1.5807	3.51
21	1.380	1.6211	3.68	5.962	1.55	.0374	1.4174	1.6888	3.54
22	1.439	1.7262	3.73	6.416	1.64	.0418	1.4808	1.8022	3.56

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 151.
Crest length, 6.550 feet.
Crest height, 2.46 feet.

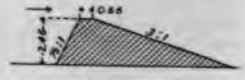


Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.201	0.0901	2.71	0.244	0.09	0.0001	0.2011	0.0901	2.71
2	.240	.1176	2.81	.329	.12	.0002	.2422	.1191	2.76
3	.307	.1701	2.79	.474	.17	.0004	.3074	.1701	2.79
4	.391	.2445	2.79	.684	.24	.0009	.3919	.2454	2.79
5	.445	.2969	2.92	.867	.30	.0014	.4464	.2979	2.91
6	.514	.3685	2.95	1.089	.37	.0021	.5161	.3707	2.94
7	.537	.3935	2.98	1.174	.39	.0024	.5394	.3957	2.97
8	.573	.4337	3.05	1.324	.43	.0030	.5760	.4371	3.03
9	.643	.5156	3.09	1.594	.51	.0040	.6470	.5204	3.06
10	.695	.5795	3.20	1.856	.59	.0054	.7004	.5857	3.17
11	.756	.6574	3.24	2.129	.66	.0068	.7628	.6665	3.19
12	.800	.7155	3.30	2.362	.72	.0081	.8081	.7263	3.25
13	.826	.7507	3.31	2.486	.76	.0090	.8350	.7631	3.26
14	.867	.8073	3.36	2.712	.81	.0102	.8772	.8213	3.30
15	.921	.8839	3.39	2.997	.89	.0123	.9333	.9013	3.32
16	.975	.9628	3.46	3.332	.97	.0146	.9896	.9850	3.38
17	1.027	1.0408	3.51	3.653	1.04	.0168	1.0438	1.0667	3.47
18	1.090	1.1380	3.52	4.013	1.13	.0199	1.1099	1.1695	3.43
19	1.112	1.1727	3.57	4.177	1.17	.0213	1.1333	1.2060	3.46
20	1.140	1.2172	3.60	4.382	1.22	.0231	1.1631	1.2543	3.50
21	1.209	1.3294	3.61	4.801	1.31	.0267	1.2357	1.3741	3.49
22	1.248	1.3942	3.64	5.060	1.36	.0288	1.2768	1.4431	3.51
23	1.314	1.5063	3.68	5.557	1.47	.0336	1.3476	1.5651	3.55
24	1.352	1.5721	3.71	6.825	1.52	0359	1.3879	1.6352	3.56
25	1.416	1.6850	3.75	6.337	1.64	.0418	1.4578	1.7604	3.60

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 153.
Crest length, 6.515 feet.
Crest height, 2.46 feet.



Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.237	0.1154	2.73	0.314	0.12	0.0002	0.2372	0.1154	2.72
2	.301	.1651	2.77	.457	.16	.0004	.3014	.1651	2.77
3	.372	.2269	2.79	.633	.22	.0008	.3728	.2278	2.78
4	.373	.2278	2.83	.645	.23	.0008	.3738	.2287	2.82
5	.440	.2919	2.90	.847	.29	.0013	.4413	.2929	2.89
6	.505	.3589	2.93	1.052	.35	.0019	.5069	.3610	2.91
7	.576	.4371	3.00	1.311	.43	.0030	.5790	.4406	2.98
8	.637	.5084	3.07	1.560	.50	.0039	.6409	.5132	3.04
9	.696	.5807	3.10	1.801	.57	.0051	.7011	.5870	3.07
10	.701	.5870	3.10	1.820	.58	.0052	.7062	.5933	3.07
11	.760	.6626	3.15	2.085	.65	.0066	.7666	.6717	3.10
12	.762	.6652	3.16	2.101	.65	.0066	.7686	.6743	3.12
13	.814	.7344	3.20	2.349	.72	.0081	.8221	.7452	3.15
14	.879	.8241	3.25	2.678	.80	.0099	.8889	.8381	3.20
15	.937	.9071	3.29	2.984	.88	.0120	.9490	.9245	3.23
16	.993	.9895	3.34	3.307	.96	.0143	1.0073	1.0105	3.27
17	1.001	1.0015	3.33	3.330	.96	.0143	1.0153	1.0226	3.26
18	1.055	1.0836	3.40	3.672	1.05	.0171	1.0721	1.1099	3.31
19	1.102	1.1569	3.41	3.956	1.11	.0192	1.1212	1.1869	3.33
20	1.170	1.2656	3.46	4.394	1.21	.0228	1.1928	1.3030	3.37
21	1.226	1.3575	3.48	4.733	1.28	.0255	1.2515	1.3992	3.38
22	1.290	1.4652	3.51	5.159	1.38	.0296	1.3196	1.5166	3.40
23	1.289	1.4635	3.52	5.139	1.37	.0292	1.3182	1.5132	3.40
24	1.347	1.5634	3.53	5.507	1.45	.0327	1.3791	1.6193	3.40
25	1.404	1.6636	3.58	5.943	1.54	.0369	1.4409	1.7298	3.44
26	1.436	1.7208	3.58	6.158	1.58	.0388	1.4748	1.7914	3.44

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 154.
Crest length, 6.516 feet.
Crest height, 2.46 feet.

Cross section.

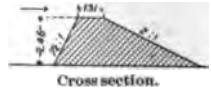
Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.236	0.1147	2.70	0.311	0.12	0.0002	0.2632	0.1349	2.30
2	.308	.1709	2.74	.469	.17	.0004	.3084	.1709	2.74
3	.373	.2278	2.83	.645	.23	.0008	.3738	.2287	2.82
4	.447	.2989	2.85	.852	.29	.0013	.4483	.2999	2.84
5	.508	.3621	2.95	1.068	.36	.0020	.5100	.3642	2.94
6	.577	.4382	2.97	1.301	.37	.0021	.5791	.4406	2.95
7	.643	.5156	3.04	1.569	.51	.0040	.6470	.5204	3.02
8	.706	.5933	3.07	1.821	.57	.0051	.7111	.5996	3.04
9	.760	.6626	3.17	2.102	.65	.0066	.7666	.6717	3.11
10	.823	.7466	3.20	2.389	.73	.0083	.8313	.7576	3.16
11	.888	.8368	3.20	2.678	.80	.0099	.8979	.8509	3.15
12	.946	.9201	3.24	2.981	.87	.0118	.9578	.9376	3.18
13	1.011	1.0165	3.28	3.334	.96	.0143	1.0253	1.0377	3.21
14	1.075	1.1146	3.31	3.674	1.03	.0165	1.0915	1.1396	3.22
15	1.138	1.2140	3.36	4.066	1.13	.0199	1.1579	1.2461	3.26
16	1.195	1.3063	3.37	4.415	1.20	.0224	1.2174	1.3426	3.29
17	1.250	1.3975	3.40	4.760	1.28	.0255	1.2755	1.4397	3.31
18	1.310	1.4994	3.43	5.145	1.36	.0288	1.3388	1.5494	3.32
19	1.370	1.6035	3.45	5.520	1.44	.0322	1.4022	1.6601	3.32
20	1.430	1.7100	3.48	5.951	1.53	.0364	1.4664	1.7750	3.35

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 156.
Crest height, 2.46 feet.
Crest width, 0.66 foot.
Upstream slope, ¼ to 1.
Downstream slope, 5 to 1.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.246	0.1220	2.76	0.337	0.12	0.0002	0.2462	0.1220	2.76
2	.311	.1734	2.80	.486	.17	.0004	.3114	.1734	2.80
3	.382	.2361	2.84	.671	.24	.0009	.3829	.2370	2.83
4	.446	.2979	2.90	.864	.30	.0014	.4474	.2989	2.89
5	.508	.3621	2.91	1.054	.36	.0020	.5100	.3642	2.89
6	.576	.4371	2.95	1.289	.42	.0027	.5787	.4406	2.92
7	.638	.5096	3.01	1.534	.49	.0037	.6417	.5144	2.98
8	.703	.5895	3.06	1.804	.57	.0051	.7081	.5958	3.03
9	.764	.6678	3.10	2.070	.64	.0064	.7704	.6757	3.06
10	.834	.7617	3.13	2.384	.72	.0081	.8421	.7727	3.08
11	.888	.8368	3.17	2.653	.79	.0097	.8977	.8510	3.12
12	.956	.9347	3.24	3.028	.88	.0120	.9680	.9524	3.18
13	1.018	1.0272	3.22	3.309	.95	.0140	1.0320	1.0484	3.16
14	1.074	1.1130	3.30	3.673	1.04	.0168	1.0908	1.1396	3.22
15	1.139	1.2156	3.29	3.999	1.11	.0192	1.1582	1.2462	3.21
16	1.203	1.3194	3.31	4.367	1.19	.0220	1.2250	1.3558	3.22
17	1.267	1.4262	3.34	4.764	1.26	.0247	1.2917	1.4686	3.24
18	1.341	1.5529	3.36	5.218	1.37	.0292	1.3702	1.6035	3.25
19	1.394	1.6459	3.36	5.530	1.43	.0318	1.4258	1.7028	3.25
20	1.457	1.7587	3.39	5.962	1.52	.0359	1.4929	1.8241	3.27

Bazin's Series, No. 158.
Crest length, 6.520 feet.
Crest height, 2.46 feet.



Cross section.

1	0.234	0.1132	2.79	0.316	0.12	0.0002	0.2342	0.1132	2.79
2	.312	.1743	2.72	.474	.17	.0004	.3124	.1743	2.72
3	.383	.2370	2.77	.656	.23	.0008	.3838	.2379	2.76
4	.457	.3090	2.79	.862	.29	.0013	.4583	.3100	2.78
5	.530	.3858	2.81	1.085	.36	.0020	.5320	.3880	2.80
6	.600	.4648	2.82	1.311	.43	.0030	.6030	.4683	2.80
7	.672	.5509	2.86	1.576	.50	.0039	.6759	.5557	2.84
8	.733	.6276	2.90	1.821	.57	.0051	.7381	.6340	2.87
9	.799	.7142	2.91	2.078	.64	.0064	.8054	.7223	2.88
10	.860	.7975	2.95	2.354	.71	.0078	.8678	.8087	2.91
11	.930	.8969	3.00	2.691	.79	.0097	.9397	.9114	2.95
12	.984	.9761	3.04	2.967	.86	.0115	.9955	.9925	2.99
13	1.055	1.0836	3.10	3.348	.95	.0140	1.0690	1.1053	3.03
14	1.125	1.1933	3.12	3.713	1.04	.0168	1.1418	1.2204	3.04
15	1.177	1.2769	3.15	4.022	1.10	.0188	1.1958	1.3029	3.08
16	1.243	1.3858	3.19	4.434	1.20	.0224	1.2654	1.4228	3.12
17	1.297	1.4771	3.22	4.766	1.27	.0251	1.3221	1.5200	3.14
18	1.361	1.5878	3.25	5.168	1.35	.0283	1.3893	1.6370	3.16
19	1.412	1.6779	3.30	5.544	1.43	.0348	1.4468	1.7406	3.18
20	1.457	1.7587	3.32	5.839	1.49	.0345	1.4915	1.8215	3.22

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 159.
Crest length, 6.511 feet.
Crest height, 2.46 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.234	0.1132	2.68	0.303	0.11	0.0002	0.2342	0.1132	2.68
2	.304	.1676	2.75	.462	.17	.0004	.3044	.1676	2.74
3	.379	.2333	2.82	.657	.23	.0008	.3798	.2342	2.80
4	.387	.2408	2.82	.680	.24	.0009	.3879	.2417	2.81
5	.457	.3090	2.81	.868	.30	.0014	.4584	.3100	2.80
6	.516	.3707	2.91	1.079	.36	.0020	.5180	.3728	2.89
7	.526	.3815	2.84	1.085	.36	.0020	.5280	.3836	2.83
8	.599	.4636	2.82	1.308	.43	.0030	.6020	.4671	2.81
9	.664	.5411	2.87	1.553	.50	.0039	.6679	.5460	2.84
10	.670	.5484	2.83	1.552	.49	.0037	.6737	.5533	2.80
11	.735	.6302	2.88	1.813	.56	.0049	.7399	.6366	2.85
12	.797	.7115	2.94	2.092	.64	.0064	.8034	.7196	2.91
13	.861	.7989	2.99	2.389	.72	.0081	.8693	.8101	2.95
14	.876	.8199	2.94	2.411	.72	.0081	.8843	.8311	2.90
15	.935	.9042	2.93	2.649	.78	.0095	.9445	.9172	2.89
16	.994	.9910	3.01	2.983	.86	.0115	1.0055	1.009	2.96
17	1.068	1.1037	3.03	3.333	.94	.0137	1.0817	1.1255	2.96
18	1.126	1.1948	3.10	3.704	1.03	.0165	1.1425	1.2204	3.04
19	1.145	1.2252	3.05	3.751	1.04	.0168	1.1618	1.2526	3.00
20	1.198	1.3112	3.08	4.035	1.10	.0188	1.2168	1.3425	3.00
21	1.261	1.4161	3.11	4.416	1.19	.0220	1.2830	1.4533	3.03
22	1.320	1.5166	3.15	4.777	1.27	.0251	1 3451	1.5599	3.06
23	1.332	1.5373	3.13	4.820	1.27	.0251	1.3571	1.5808	3.05
24	1.389	1.6370	3.14	5.150	1.33	.0275	1.4165	1.6850	3.06
25	1.445	1.7370	3.19	5.551	1.42	.0313	1.4763	1.7932	3.09
26	1.456	1.7569	3.19	5.614	1.43	.0348	1.4908	1.8188	3.09

***Bazin's experiments on** weirs of irregular section*—Continued.

Bazin's Series, No. 160.
Crest height, 2.46 feet.
Crest width, 1.31 feet.
Upstream slope, ¼ to 1.
Downstream slope, 6 to 1.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.451	0.3029	2.81	0.8540	0.29	0.0013	0.4523	0.3039	2.80
2	.522	.3772	2.82	1.0637	.36	.0020	.5240	.3793	2.80
3	.593	.4567	2.84	1.2970	.42	.0027	.5957	.4601	2.82
4	.663	.5399	2.88	1.5549	.50	.0039	.6669	.5447	2.86
5	.735	.6302	2.89	1.8213	.57	.0051	.7401	.6366	2.86
6	.798	.7128	2.91	2.0742	.64	.0064	.8044	.7209	2.88
7	.863	.8017	2.92	2.3410	.70	.0076	.8706	.8129	2.88
8	.930	.8969	2.97	2.6638	.78	.0095	.9395	.9100	2.93
9	.998	.9970	2.99	2.9810	.86	.0115	1.0095	1.0135	2.94
10	1.074	1.1130	3.02	3.3361	.95	.0140	1.0880	1.1349	2.94
11	1.129	1.1996	3.03	3.6348	1.01	.0159	1.1449	1.2252	2.97
12	1.193	1.3030	3.06	3.9872	1.09	.0185	1.2115	1.3334	2.98
13	1.254	1.4043	3.08	4.3252	1.16	.0209	1.2749	1.4397	3.00
14	1.326	1.5269	3.10	4.7334	1.25	.0243	1.3503	1.5686	3.02
15	1.389	1.6370	3.14	5.1402	1.34	.0279	1.4169	1.6867	3.05
16	1.457	1.7587	3.16	5.5575	1.42	.0313	1.4883	1.8151	3.06

Bazin's Series, No. 161.
Crest length, 6.543 feet.
Crest height, 1.64 feet.

Cross section.

1	0.298	0.1627	4.31	0.701	0.36	0.0020	0.3000	0.1643	4.27
2	.354	.2107	4.30	.906	.45	.0031	.3571	.2133	4.25
3	.413	.2654	4.26	1.131	.56	.0049	.4179	.2702	4.19
4	.472	.3243	4.23	1.371	.65	.0066	.4786	.3314	4.14
5	.529	.3847	4.22	1.625	.75	.0087	.5377	.3946	4.12
6	.581	.4429	4.25	1.883	.85	.0112	.5922	.4555	4.13
7	.639	.5108	4.24	2.167	.95	.0140	.6530	.5277	4.11
8	.693	.5770	4.26	2.458	1.05	.0171	.7101	.5983	4.11
9	.750	.6495	4.28	2.782	1.16	.0209	.7709	.6770	4.11
10	.804	.7209	4.31	3.107	1.27	.0251	.8291	.7548	4.12
11	.864	.8031	4.31	3.461	1.38	.0296	.8936	.8452	4.10
12	.919	.8810	4.32	3.806	1.49	.0345	.9535	.9303	4.09
13	.960	.9406	4.33	4.073	1.57	.0383	.9983	.9970	4.08
14	.992	.9880	4.30	4.248	1.61	.0403	1.0323	1.0484	4.05
15	1.019	1.0287	4.31	4.434	1.67	.0434	1.0624	1.0944	4.05
16	1.056	1.0851	4.28	4.665	1.72	.0460	1.1020	1.1569	4.03
17	1.083	1.1271	4.27	4.825	1.78	.0493	1.1323	1.2044	4.01
18	1.118	1.1821	4.24	5.003	1.81	.0509	1.1689	1.2640	3.96
19	1.157	1.2445	4.17	5.171	1.84	.0526	1.2096	1.3310	3.88
20	1.187	1.2932	4.16	5.380	1.90	.0561	1.2431	1.3858	3.88
21	1.225	1.3558	4.12	5.378	1.95	.0591	1.2841	1.4550	3.83
22	1.263	1.4194	4.09	5.808	2.00	.0622	1.3252	1.5252	3.81
23	1.289	1.4635	4.11	6.001	2.05	.0653	1.3543	1.5756	3.81
24	1.326	1.5269	4.08	6.242	2.10	.0686	1.3946	1.6476	3.79
25	1.359	1.5843	4.08	6.446	2.15	.0719	1.4309	1.7118	3.76

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 163.
Crest length, 6.535 feet.
Crest height, 1.64 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.184	0.0790	3.81	0.301	0.17	0.0004	0.1844	0.0790	3.81
2	.244	.1206	3.83	.463	.25	.0009	.2449	.1213	3.82
3	.303	.1668	3.84	.641	.33	.0017	.3047	.1684	3.81
4	.366	.2215	3.83	.850	.42	.0027	.3687	.2241	3.79
5	.423	.2754	3.83	1.053	.51	.0040	.4270	.2791	3.77
6	.486	.3388	3.82	1.295	.61	.0058	.4915	.3441	3.76
7	.536	.3924	3.86	1.513	.69	.0074	.5434	.4001	3.78
8	.593	.4567	3.94	1.799	.81	.0102	.6032	.4683	3.84
9	.653	.5277	3.91	2.063	.90	.0126	.6656	.5435	3.80
10	.702	.5882	4.04	2.376	1.01	.0159	.7179	.6084	3.90
11	.769	.6744	3.98	2.683	1.11	.0188	.7878	.6995	3.84
12	.827	.7521	4.02	3.023	1.22	.0231	.8501	.7837	3.86
13	.882	.8283	4.02	3.329	1.32	.0271	.9091	.8667	3.84
14	.949	.9245	4.04	3.735	1.44	.0322	.9812	.9717	3.84
15	.998	.9970	4.06	4.048	1.53	.0364	1.0344	1.0514	3.85
16	1.056	1.0851	4.06	4.425	1.64	.0418	1.0978	1.1505	3.85
17	1.114	1.1758	4.05	4.779	1.74	.0471	1.1611	1.2510	3.82
18	1.171	1.2672	4.07	5.169	1.84	.0526	1.2236	1.3541	3.82
19	1.231	1.3658	4.07	5.576	1.94	.0585	1.2895	1.4635	3.81
20	1.285	1.4567	4.12	6.014	2.06	.0660	1.3510	1.5703	3.83
21	1.339	1.5495	4.17	6.464	2.17	.0732	1.4122	1.6779	3.85

Bazin's Series, No. 164.
Crest length, 6.534 feet.
Crest height, 1.64 feet.

Cross section.

1	0.244	0.1206	3.86	0.467	0.25	0.0009	0.2449	0.1213	3.85
2	.305	.1685	3.91	.659	.34	.0018	.3068	.1701	3.88
3	.367	.2234	3.87	.859	.43	.0030	.3700	.2251	3.82
4	.425	.2771	3.90	1.080	.52	.0042	.4292	.2810	3.84
5	.482	.3346	3.87	1.296	.61	.0058	.4878	.3409	3.80
6	.540	.3968	3.87	1.536	.70	.0076	.5476	.4057	3.79
7	.592	.4555	3.94	1.797	.81	.0102	.6022	.4671	3.85
8	.651	.5252	3.94	2.069	.90	.0126	.6636	.5410	3.82
9	.702	.5882	3.97	2.334	.99	.0152	.7172	.6071	3.84
10	.766	.6705	4.00	2.684	1.11	.0188	.7848	.6955	3.86
11	.817	.7385	4.03	2.978	1.21	.0228	.8398	.7699	3.87
12	.877	.8213	4.05	3.325	1.32	.0271	.9041	.8595	3.87
13	.939	.9100	4.07	3.704	1.44	.0322	.9722	.9583	3.86
14	.993	.9895	4.10	4.055	1.54	.0369	1.0299	1.0453	3.88
15	1.052	1.0790	4.09	4.417	1.64	.0418	1.0938	1.1442	3.86
16	1.115	1.1774	4.12	4.862	1.76	.0482	1.1632	1.2543	3.88
17	1.162	1.2526	4.13	5.163	1.84	.0526	1.2146	1.3392	3.86
18	1.219	1.3459	4.15	5.602	1.96	.0597	1.2787	1.4465	3.87
19	1.277	1.4431	4.18	6.019	2.06	.0660	1.3430	1.5564	3.87
20	1.330	1.5338	4.19	6.411	2.16	.0725	1.4025	1.6601	3.86

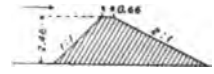
Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 165.
Crest length, 6.544 feet.
Crest height, 1.64 feet.

Cross section.

Period.	Observed head, experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.337	0.1957	3.56	0.698	0.35	0.0019	0.3389	0.1974	3.54
2	.401	.2540	3.56	.904	.44	.0030	.4040	.2568	3.52
3	.464	.3161	3.56	1.125	.54	.0045	.4685	.3202	3.51
4	.528	.3836	3.55	1.363	.63	.0062	.5342	.3902	3.49
5	.593	.4567	3.54	1.618	.73	.0083	.6013	.4660	3.47
6	.656	.5313	3.54	1.880	.82	.0105	.6665	.5435	3.46
7	.720	.6109	3.54	2.162	.92	.0132	.7332	.6276	3.44
8	.783	.6929	3.55	2.461	1.02	.0162	.7992	.7142	3.45
9	.843	.7740	3.58	2.771	1.11	.0192	.8622	.8003	3.46
10	.904	.8595	3.61	3.103	1.22	.0231	.9271	.8926	3.47
11	.969	.9538	3.63	3.462	1.33	.0275	.9965	.9940	3.48
12	1.029	1.0438	3.63	3.789	1.42	.0313	1.0603	1.0913	3.47
13	1.090	1.1380	3.64	4.150	1.52	.0359	1.1259	1.1948	3.47
14	1.153	1.2381	3.65	4.526	1.62	.0408	1.1938	1.3046	3.47
15	1.217	1.3426	3.66	4.904	1.71	.0455	1.2625	1.4178	3.46
16	1.279	1.4465	3.68	5.336	1.83	.0521	1.3311	1.5355	3.48
17	1.341	1.5529	3.68	5.704	1.92	.0573	1.3983	1.6530	3.45
18	1.401	1.6583	3.69	6.125	2.02	.0634	1.4644	1.7714	3.46
19	1.448	1.7424	3.73	6.490	2.10	.0686	1.5166	1.8680	3.47

Bazin's Series, No. 176.
Crest length, 6.519 feet.
Crest height, 2.46 feet.

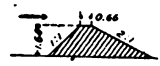


Cross section.

1	0.237	0.1154	2.76	0.317	0.12	0.0002	0.2372	0.1154	2.75
2	.296	.1611	2.74	.441	.16	.0004	.2964	.1611	2.74
3	.365	.2206	2.92	.645	.23	.0008	.3658	.2214	2.91
4	.439	.2909	2.95	.858	.30	.0014	.4404	.2919	2.94
5	.494	.3472	3.04	1.055	.36	.0020	.4960	.3494	3.02
6	.565	.4247	3.10	1.318	.43	.0030	.5680	.4281	3.08
7	.618	.4858	3.19	1.550	.50	.0039	.6219	.4905	3.16
8	.682	.5632	3.22	1.813	.58	.0052	.6872	.5695	3.18
9	.733	.6276	3.29	2.066	.65	.0066	.7396	.6366	3.24
10	.797	.7115	3.35	2.385	.73	.0083	.8073	.7250	3.29
11	.861	.7989	3.41	2.724	.82	.0105	.8715	.8129	3.35
12	.910	.8681	3.45	2.995	.89	.0123	.9223	.8853	3.38
13	.974	.9613	3.51	3.373	.98	.0149	.9889	.9835	3.43
14	1.027	1.0408	3.53	3.671	1.05	.0171	1.0441	1.0667	3.44
15	1.088	1.1349	3.57	4.034	1.14	.0202	1.1082	1.1663	3.46
16	1.139	1.2156	3.62	4.416	1.23	.0235	1.1625	1.2526	3.52
17	1.196	1.3079	3.65	4.782	1.30	.0263	1.223	1.3508	3.54
18	1.248	1.3942	3.68	5.115	1.38	.0296	1.2776	1.4448	3.54
19	1.303	1.4874	3.73	5.558	1.47	.0336	1.3366	1.5460	3.60
20	1.355	1.5773	3.75	5.925	1.55	.0374	1.3924	1.6423	3.61
21	1.420	1.6921	3.80	6.422	1.66	.0428	1.4628	1.7695	3.63

Bazin's experiments on weirs of irregular section—Continued.

Bazin's Series, No. 178.
Crest length, 6.518 feet.
Crest height, 2.46 feet.



Cross section.

Period.	Observed head experimental weir D, in feet.	$D^{\frac{3}{2}}$	C_1	Q, flow per foot, experimental weir, in cubic feet per second.	v	$\frac{v^2}{2g}$	H	$H^{\frac{3}{2}}$	C
1	2	3	4	5	6	7	8	9	10
1	0.222	0.1046	2.83	0.297	0.11	0.0002	0.2222	0.1046	2.84
2	.299	.1635	2.95	.482	.17	.0004	.2994	.1635	2.95
3	.367	.2224	2.96	.658	.23	.0008	.3678	.2233	2.95
4	.431	.2830	3.08	.872	.30	.0014	.4324	.2840	3.07
5	.491	.3441	3.13	1.077	.37	.0021	.4931	.3462	3.11
6	.556	.4146	3.19	1.323	.47	.0034	.5594	.4180	3.16
7	.614	.4811	3.24	1.558	.51	.0040	.6180	.4858	3.21
8	.669	.5472	3.28	1.794	.57	.0051	.6741	.5533	3.24
9	.732	.6263	3.33	2.085	.65	.0066	.7386	.6353	3.28
10	.789	.7009	3.36	2.355	.73	.0083	.7973	.7115	3.31
11	.847	.7796	3.43	2.675	.81	.0102	.8572	.7934	3.37
12	.906	.8624	3.46	2.983	.89	.0123	.9183	.8795	3.39
13	.966	.9494	3.51	3.331	.97	.0146	.9806	.9716	3.43
14	1.028	1.0423	3.53	3.671	1.05	.0171	1.0451	1.0683	3.44
15	1.083	1.1271	3.58	4.045	1.14	.0202	1.1032	1.1584	3.49
16	1.142	1.2204	3.60	4.392	1.22	.0231	1.1651	1.2575	3.49
17	1.195	1.3063	3.64	4.755	1.30	.0263	1.2213	1.3492	3.52
18	1.259	1.4127	3.66	5.170	1.39	.0300	1.2890	1.4635	3.53
19	1.314	1.5063	3.69	5.572	1.48	.0341	1.3481	1.5651	3.56
20	1.366	1.5965	3.72	5.952	1.55	.0374	1.4034	1.6618	3.58
21	1.424	1.6992	3.75	6.375	1.65	.0423	1.4663	1.7750	3.59

CORNELL UNIVERSITY HYDRAULIC LABORATORY.[a]

is laboratory, erected in 1898, includes a reservoir formed by a nry dam on Fall Creek, at Ithaca, N. Y. An experimental chan- ; supplied with water from the pond and has, as its general nsions, length, 400 feet; breadth, 16 feet; depth, 10 feet; bottom ;, 1:500. Fall Creek drains an area of 117 square miles, and ls a minimum water supply estimated at 12 second-feet. The aulic laboratory is located at Triphammer Falls, where a descent 9 feet occurs. The weirs used in the experiments here described erected in the concrete-lined experimental channel. The water ly was regulated by wooden head-gates, operated by lever, rack, inion, the outflow from the canal passing over the declivity below.

reducing the experiments at Cornell hydraulic laboratory the value of g for Ithaca, latitude altitude 500 feet, has been taken as 32.16, making $\sqrt{2g}=8.02$, $\frac{1}{\sqrt{2g}}=0.015517$, $\frac{2}{3}\sqrt{2g}=5.35$.

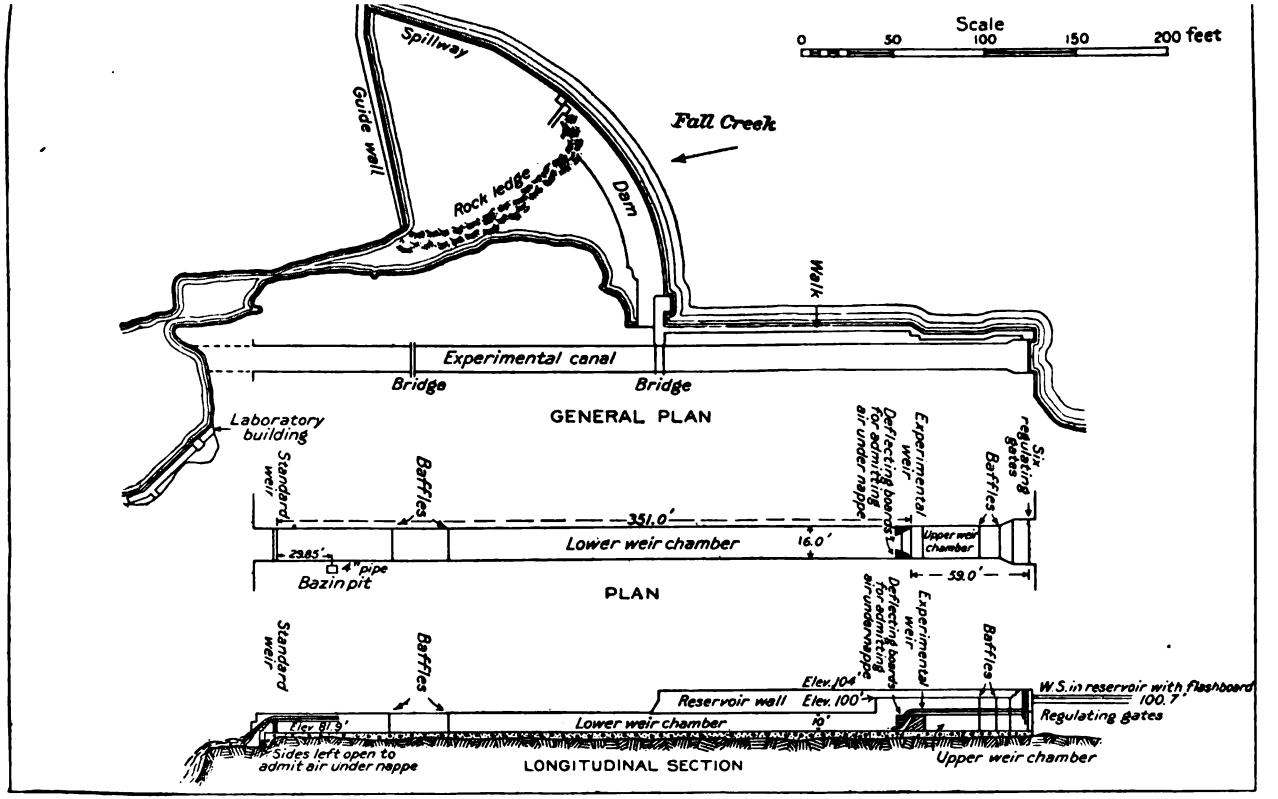
EXPERIMENTS OF UNITED STATES BOARD OF ENGINEERS ON DEEP WATERWAYS.

These experiments were performed at Cornell University hydraulic laboratory in May and June, 1899, for the United States Board of Engineers on Deep Waterways, under the immediate direction of George W. Rafter, engineer for water supply, in conjunction with Prof. Gardner S. Williams. The results of the original computations were published in Trans. Am. Soc. C. E., vol. 44, together with an extended discussion. In the experiments a closely regulated volume of water was passed over a standard thin-edged weir which was placed near the upper end of the experimental canal and had a height of 13.13 feet and a crest length of 16 feet, end contractions suppressed. The nappe was aerated, but was not allowed to expand on downstream side. The water flowed down the experimental canal past a series of screens and baffles and over the experimental weir placed at the lower end of the channel.

The experimental weirs were about 4.5 feet high and 6.56 feet crest length. A leading channel of planed boards, 6.56 feet wide and 48 feet in length, extended upstream from the experimental weir, having at its upper end flaring sides extending 8.3 feet upstream and meeting the sides of the main channel.

The head on both weirs was read by means of open manometers connected to galvanized-iron piezometer pipes, placed horizontally across the bottom of the narrow leading channel, 37 feet upstream from the weir. At the standard weir two piezometers were used, one termed the middle piezometer, placed across the leading channel, 8 inches above the bottom and 10 feet upstream from the standard weir. A second or upstream piezometer was placed 25 feet upstream from the standard weir. Readings of both piezometers were taken. It was decided, however, to use the middle piezometer as the basis of calculation of discharge over the standard weir. Near the close of the experiments it was found that this did not give results agreeing with those which would have been obtained from a piezometer placed flush with the bottom of the channel, as is shown to be necessary from the experiments of H. F. Mills[a] and others. A correction curve was accordingly deduced from comparative experiments between the middle piezometer and the flush piezometer, and the readings of the middle piezometer thus corrected were applied in the Bazin formula to calculate the discharge over the standard weir for heads not exceeding the limit of Bazin's experiments. For depths on the standard weir greater than 2 feet the discharge was computed by using coefficients deduced for higher heads on a shorter experimental weir, on the basis of the Francis formula. Owing to the uncertainty as to the piezometers and

[a] Mills, H. F., Experiments upon piezometers used in hydraulic investigations, Boston, 1878.



HYDRAULIC LABORATORY AT CORNELL UNIVERSITY, ITHACA, N. Y.

ELL HYDRAULIC LABORATORY, ARRANGED FOR WEIR EXPERIMENTS.

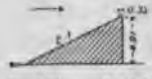
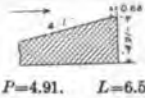
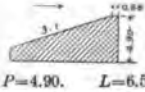
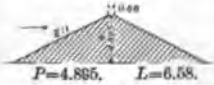
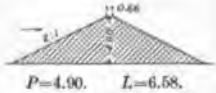
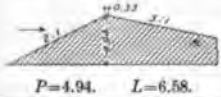
ıer conditions, the original results of the experiments were credited th a possible error of 5 or 6 per cent.

In connection with the experiments on models of the Croton dam, a y thorough comparison of the so-called upstream piezometer with ıer methods of obtaining the head on a standard weir was made by ofessor Williams. It was found that the upstream piezometer gave actual head on the standard weir correctly. These results were comnicated to the writer, and a recomputation of the Deep Waterways periments has been made, using readings of the upstream piezome- to calculate the standard weir discharge by Bazin's formula. This thod of calculation eliminates the necessity for correcting the pieneter readings at the standard weir, as was necessary in the previous luctions. The discharge over the experimental weir has been calated from readings of a piezometer placed 38 feet upstream from weir and 8 inches above channel bottom, corrected to the basis of ush piezometer.

The United States Deep Waterways experiments included, for each perimental model, a smaller number of heads or periods than either Croton or United States Geological Survey experiments. They re also the first experiments of the kind conducted at the Cornell oratory, and the experience gained has probably contributed to the uring of somewhat greater accuracy in the later experiments. It is ieved, however, that, as recomputed, the United States Deep Waterys experiments do not differ much in accuracy from those made on dels of the Croton dam, which are stated by John R. Freeman to reliable within about 2 per cent. The coefficients obtained by omputation, when compared with the original United States Deep aterways coefficients, show few differences exceeding 2 per cent. e variations are plus and minus in about equal numbers, and it is ieved that these experiments are entitled to greater weight than y have hitherto received.

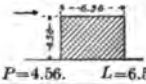
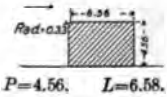
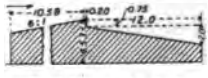
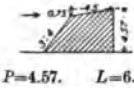
n the accompanying tables a summary of the recomputation is en.

Recomputation of United States Deep Waterways Board experiments on flow of water over model dams, Cornell University hydraulic laboratory, 1899.

Weir model.	Period.	Corrected depth D, experimental weir, centimeters.	D, in feet.	Q= flow per foot, in cubic feet per second.	V	$h=\frac{V^2}{2g}$	$H=D+h$	C_1	Number of observations of head.
1	2	3	4	5	6	7	8	9	10
Series 1.  P=4.91. L=6.58.	1	.....	4.972	39.73	.....	.....	4.972	3.584	.....
	2	.....	4.872	39.44	.....	.....	4.872	3.668	.....
	3	.....	4.853	39.31	.....	.....	4.853	3.940	.....
	4	.....	4.138	31.47	.....	.....	4.138	3.739	.....
	5	.....	3.368	22.81	.....	.....	3.368	3.690	.....
	6	.....	1.725	8.71	.....	.....	1.725	3.844	.....
	7	.....	1.190	4.88	.....	.....	1.190	3.759	.....
Series 2. P=4.90. L=6.58.	1	.....	5.05	42.13	.....	.....	5.050	3.712	41
	2	.....	4.15	31.17	.....	.....	4.150	3.758	23
	3	.....	3.35	22.89	.....	.....	3.350	3.733	13
	4	.....	2.55	15.03	.....	.....	2.550	3.691	21
	5	.....	1.75	8.39	.....	.....	1.750	3.633	15
	6	.....	.923	3.02	.....	.....	.923	3.406	18
	7	.....	.34	.82	.....	.....	.340	4.120	7
Series 3. P=4.91. L=6.58.	1	.....	.....	.....	.....	.....	5.23	3.393	21
	2	.....	.....	.....	.....	.....	3.49	3.383	15
	3	.....	.....	.....	.....	.....	1.75	3.382	21
Series 4.  P=4.91. L=6.58.	1	.....	.....	.....	.....	.....	5.11	3.547	21
	2	.....	.....	.....	.....	.....	4.28	3.373	27
	3	.....	.....	.....	.....	.....	3.43	3.484	27
	4	.....	.....	.....	.....	.....	2.57	3.485	27
	5	.....	.....	.....	.....	.....	1.73	3.485	23
	6	.....	.....	.....	.....	.....	.....	.....	.....
Series 5.  P=4.90. L=6.58.	1	146.70	4.812	41.04	4.23	0.2782	5.0902	3.574	25
	2	123.00	4.034	31.22	3.50	.1959	4.2299	3.593	31
	3	98.80	3.242	21.49	2.65	.1092	3.3512	3.503	27
	4	75.72	2.484	13.27	1.80	.0504	2.5344	3.289	25
	5	50.65	1.662	8.21	1.24	.0239	1.6859	3.751	21
Series 7.  P=4.885. L=6.58.	1	142.75	4.682	41.40	4.30	.2875	4.9695	3.737	29
	2	119.20	3.969	30.72	3.47	.1872	4.1562	3.626	29
	3	96.72	3.173	21.64	2.67	.1108	3.2838	3.637	27
	4	74.50	2.444	14.07	1.92	.0573	2.5013	3.557	27
Series 8. [a]  P=4.90. L=6.58.	1	144.00	4.723	41.22	4.28	.2848	5.0078	3.678	18
	2	120.50	3.953	30.50	3.45	.1850	4.1380	3.623	26
	3	97.27	3.192	21.53	2.62	.1067	3.299	3.591	23
	4	74.35	2.439	14.18	1.92	.0573	2.4963	3.595	27
	5	49.77	1.633	7.63	1.17	.0213	1.6543	3.585	15
Series 9.  P=4.94. L=6.58.	1	147.10	4.825	41.16	4.20	.2742	5.0992	3.575	22
	2	123.00	4.034	30.47	3.38	.1776	4.2116	3.525	29
	3	99.62	3.268	21.48	2.62	.1067	3.3927	3.437	25
	4	76.22	2.500	14.24	1.92	.0573	2.5573	3.482	
	5	51.00	1.673	7.85	1.19	.0220	1.6950	3.557	24

[a] Same as series 7, but upstream face covered with ¼-inch mesh galvanized wire netting.

Computation of United States Deep Waterways Board experiments on flow of water over model dams, Cornell University hydraulic laboratory, 1899—Continued.

Weir model.	Period.	Corrected depth D, experimental weir, centimeters.	D, in feet.	Q= flow per foot, in cubic feet per second.	V	$h=\frac{V^2}{2g}$	$H=D+h$	C_1	Number of observations of head.
1	2	3	4	5	6	7	8	9	10
Series 10.	1	153.82	5.046	42.01	4.37	0.2969	5.3429	3.402	21
	2	132.94	4.361	31.27	3.50	.1904	4.5514	3.220	21
	3	110.98	3.641	22.33	2.72	.1150	3.7560	3.068	20
	4	87.99	2.887	14.77	1.99	.0616	2.9486	2.917	17
P=4.57. L=6.58.	5	61.70	2.024	8.12	1.24	.0239	2.0479	2.771	17
Series 11.	1	149.15	4.892	42.06	4.45	.3079	5.1999	3.547	.....
	2	127.70	4.189	31.66	3.60	.2015	4.3905	3.418	.....
	3	105.60	3.464	22.02	2.72	.1150	3.5790	3.252	.....
	4	82.52	2.707	14.34	1.97	.0603	2.7673	3.115	.....
P=4.57. L=6.58.	5	58.80	1.930	8.26	1.26	.0247	1.9547	3.022	.....
Series 12.	1	154.55	5.069	30.69	3.19	.1582	5.219	2.574	.....
	2	126.80	4.160	21.58	2.48	.0956	4.2556	2.458	.....
	3	96.75	3.174	14.12	1.82	.0515	3.2255	2.438	.....
P=4.56. L=6.58.	4	66.30	2.174	7.85	1.17	.0213	2.1953	2.413	.....
Series 13.	1	144.70	4.747	30.69	3.28	.1673	4.9143	2.817	.....
	2	116.60	3.825	21.75	2.60	.1051	3.9301	2.790	.....
	3	88.52	2.904	14.07	1.90	.0561	2.9601	2.763	.....
	4	60.02	1.969	7.85	1.19	.0220	1.9910	2.859	.....
P=4.56. L=6.58.	5	30.80	1.010	2.89	.51	.0040	1.0140	2.830	.....
Series 14.	1	157.05	5.151	41.16	4.23	.2782	5.4292	3.254	.....
	2	131.60	4.317	30.64	3.45	.1850	4.5020	3.208	.....
	3	105.40	3.458	21.68	2.72	.1150	3.5730	3.212	.....
	4	80.25	2.633	14.07	1.97	.0603	2.6933	3.183	.....
	5	54.25	1.780	7.78	1.24	.0239	1.8039	3.219	.....
P=4.53. L=6.58.	6	28.05	.920	2.75	.51	.0040	.9240	3.096	.....
Series 15.	1	129.55	4.250	31.12	3.55	.1959	4.4459	3.320	.....
	2	105.00	3.444	21.87	2.72	.1150	3.5590	3.257	.....
	3	79.52	2.608	14.02	1.97	.0603	2.6683	3.217	.....
P=4.53. L=6.58.	4	53.65	1.760	7.95	1.26	.0247	1.7847	3.333	.....
Series 16.	1	126.75	4.157	30.69	3.52	.1926	4.3496	3.383	.....
	2	102.55	3.364	21.87	2.75	.1176	3.4816	3.366	.....
	3	78.02	2.559	14.02	1.97	.0603	2.6193	3.307	.....
P=4.57. L=6.58.	4	52.00	1.706	7.73	1.24	.0239	1.7299	3.397	.....
Series 17.	1	127.30	4.175	31.08	3.55	.1959	4.3709	3.401	.....
	2	103.32	3.389	21.87	2.75	.1176	3.5066	3.331	.....
	3	78.39	2.571	14.34	2.02	.0634	2.6344	3.354	.....
	4	51.57	1.691	7.73	1.24	.0239	1.7149	3.442	.....
P=4.57. L=6.58.	5	32.40	1.063	3.82	.68	.0072	1.0702	3.450	.....
Series 18.	1	38.523	1.264	5.47	.92	.0132	1.2772	3.790	.....
	2	149.362	4.899	40.19	4.23	.2782	5.1772	3.412	.....
	3	125.693	4.123	30.25	3.45	.1850	4.3080	3.383	.....
	4	100.766	3.305	21.38	2.70	.1133	3.4183	3.383	.....
P=4.65 L=6.58.	5	75.427	2.474	13.85	1.94	.0585	2.5325	3.437	.....

ecomputation of United States Deep Waterways Board experiments on flow of water over model dams, Cornell University hydraulic laboratory, 1899—Continued.

Weir model.	Period.	Corrected depth D, experimental weir, centimeters.	D, in feet.	Q= flow per foot, in cubic feet per second.	V	$h=\frac{V^2}{2g}$	$H=D+h$	C_1	Number of observations of head.
1	2	3	4	5	6	7	8	9	10
Series 19. P=5.28. L=6.58.	1	27.04	0.8869	2.75	0.44	0.0030	0.8899	3.276	.....
	2	51.36	1.685	7.46	1.07	.0178	1.7028	3.357	.....
	3	142.128	4.662	40.04	4.20	.2742	4.9362	3.651	.....
	4	119.442	3.918	29.62	3.23	.1622	4.0802	3.594	.....
	5	97.858	3.210	20.78	2.45	.0933	3.3033	3.461	.....
	6	77.246	2.534	14.17	1.82	.0515	2.5855	3.401	.....
	7	53.42	1.752	7.68	1.09	.0185	1.7705	3.260	.....

Column 5 shows the discharge over the experimental weir per foot f crest, deduced from the readings of the upstream piezometer at the andard weir, by Bazin's formula, and corrected for slight leakage.

Column 3 shows the head on the experimental weir, in centimeters, ken by a piezometer 38 feet upstream and 8 inches above channel ottom, corrected to reduce it to the equivalent reading of the flush piezometer.

Column 4 shows the equivalent head in feet.

Column 6 shows the absolute velocity of approach.

Column 7 shows the velocity head.

Column 8 shows the head corrected for velocity of approach; the correction being made by the simple addition of the velocity head to the measured head, which is assumed to be a sufficiently precise equivalent to the Francis correction formula for this purpose.

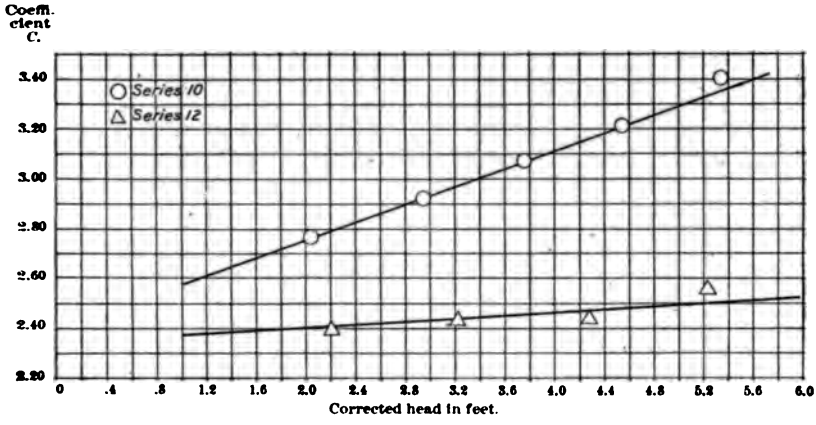
Column 9 gives the coefficient C_1, deduced from the foregoing.

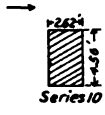
The resulting coefficient diagrams are shown on Pls. XV to XVIII, inclusive.

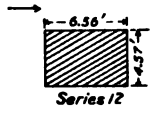
EXPERIMENTS AT CORNELL UNIVERSITY HYDRAULIC LABORATORY ON MODELS OF OLD CROTON DAM.[a]

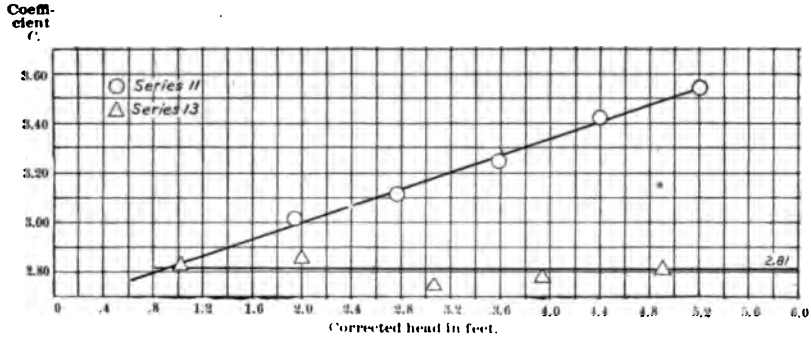
These experiments were made in November and December, 1899, by Prof. Gardner S. Williams, under the direction of John R. Freeman. The standard weir used was located near the head of the experimental canal, water being admitted and regulated by head-gates in the usual manner. The standard weir was 11.25 feet high and 16 feet long on the crest. The experimental weir was placed 232.5 feet farther downstream, and also occupied the full width of the experimental canal. The models of the Croton dam were constructed of framed timber and were 6 to 9 feet high.

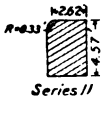
[a] Report on New York's water supply, Freeman, 1900, pp. 139-141.

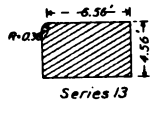




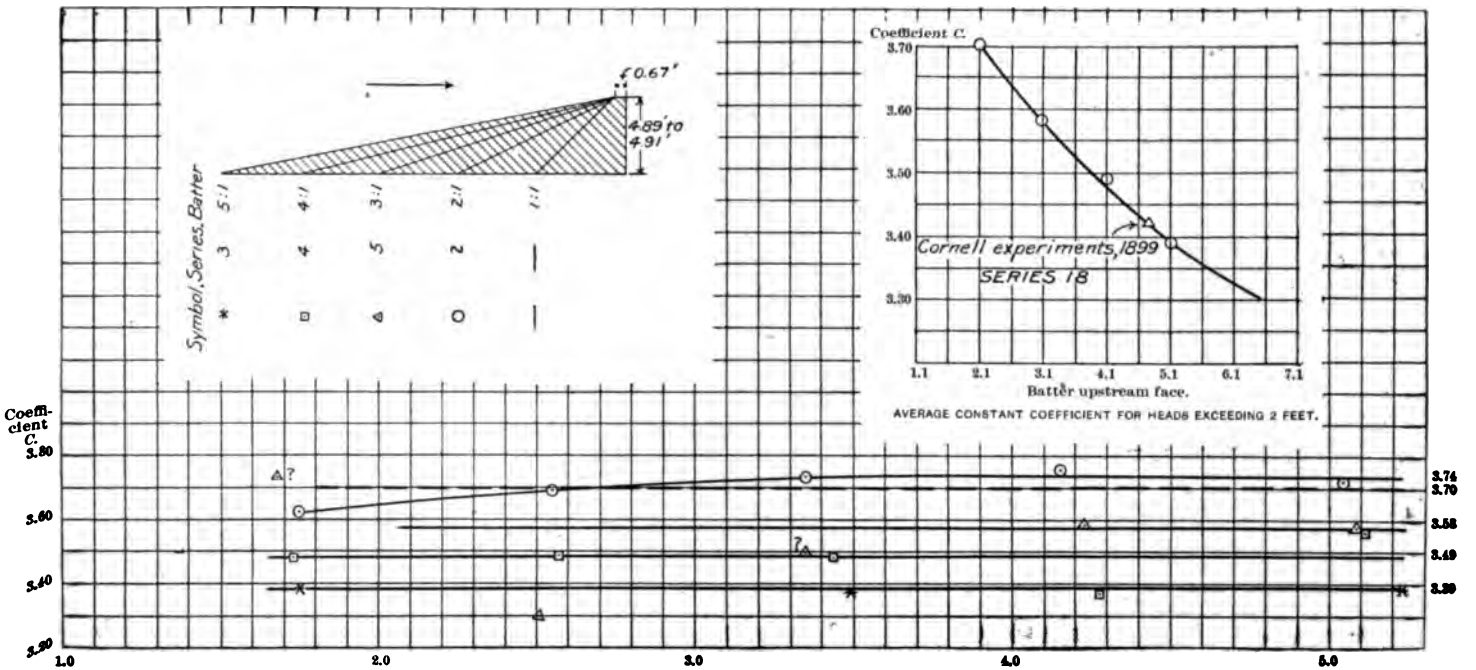




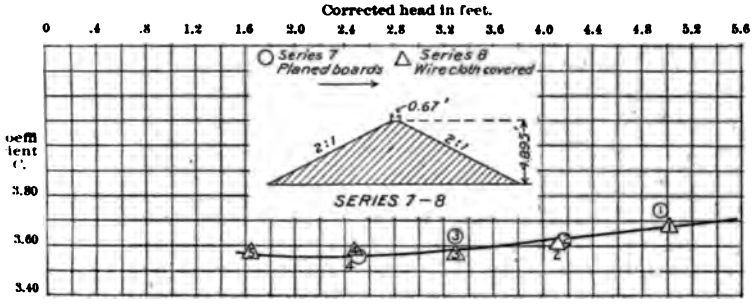


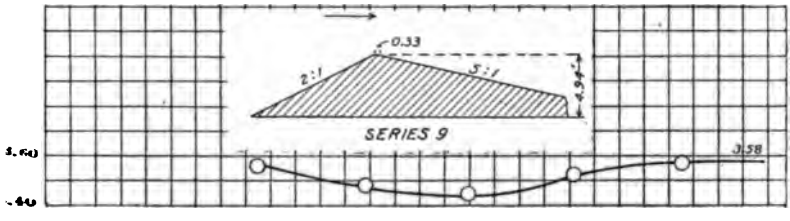


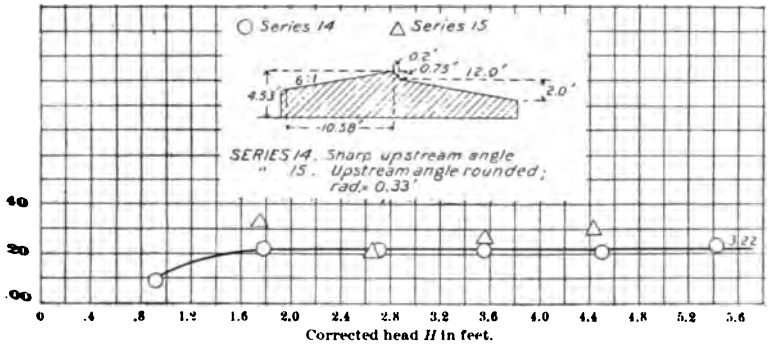
EXPERIMENTS OF UNITED STATES DEEP WATERWAYS BOARD AT CORNELL UNIVERSITY, 1899.



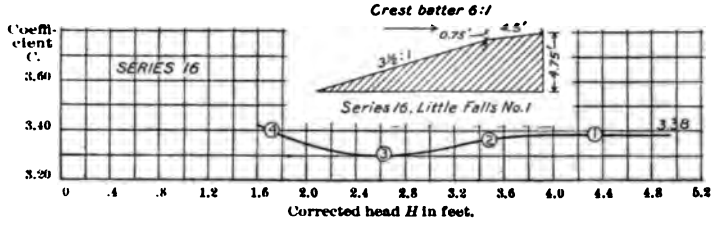
EXPERIMENTS OF UNITED STATES DEEP WATERWAYS BOARD AT CORNELL UNIVERSITY, 1899.

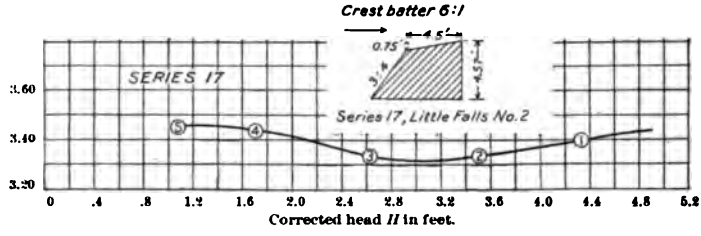


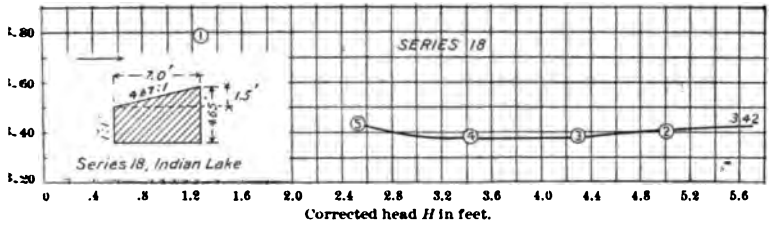


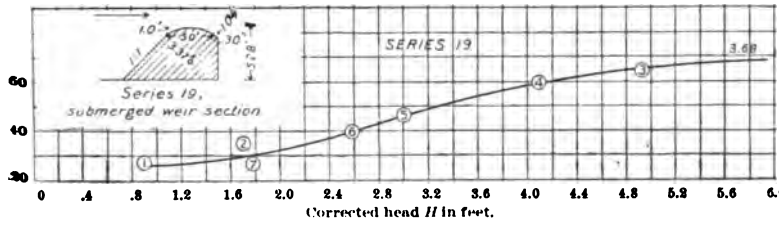


EXPERIMENTS OF UNITED STATES DEEP WATERWAYS BOARD AT CORNELL UNIVERSITY, 1899.









EXPERIMENTS OF UNITED STATES DEEP WATERWAYS BOARD AT CORNELL UNIVERSITY, 1899.

ad on the weirs was measured by means of open glass manom-
nected to piezometer tubes in the channel above each weir.
ometer tubes were made of 1-inch galvanized-iron pipe with
les drilled along the sides, the ends being plugged. At the
weir three piezometers were used, placed parallel to the cur-
about mid-depth of the channel, one being near each side and
id-width of the channel, the mid-length of the pipes being
upstream from the standard weir. A hook gage in the same
as used to check the observed head.

ts on volume of flow over models of old Croton dam, Cornell University hydraulic laboratory, 1899.

	Period No.	Observed depth on model dam, in feet.	Mean velocity of approach, in feet per second.	Correction for velocity of approach, in feet.	Corrected head on model dam, in feet.	Discharge over model dam per foot of length, in cubic feet per second.	C_1
1	2	3	4	5	6	7	8
Series 1—Model A.	1	2.7229	1.685	0.0439	2.7668	14.762	3.208
, old Croton dam, smooth pine,	2	2.1857	1.283	.0259	2.2116	10.562	3.211
slope 16 feet long. Nov. 28-29,	3	1.4388	.749	.0087	1.4475	5.604	3.218
	4	.9830	.449	.0031	.9861	3.154	3.222
	5	.5907	.219	.0008	.5915	1.451	3.190
	6	.1230	.024	.0000	.1230	.147	3.408
Series 1a—Model A.	1	2.0897	.978	.0149	2.1046	9.578	3.137
t, old Croton dam, unplaned	2	1.8293	.810	.0102	1.8395	7.883	3.160
st 16 feet long, smooth slope.	3	1.5878	.661	.0068	1.5946	6.284	3.121
9.	4	1.2562	.467	.0034	1.2596	4.287	3.032
	5	.9929	.338	.0018	.9947	3.006	3.030
	6	.6301	.175	.0004	.6305	1.494	2.988
	7	.4871	.111	.0002	.4873	.991	2.913
Series 2—Model A.	1	2.9227	1.839	.0526	2.9753	16.475	3.240
, old Croton dam, 16-foot smooth	2	2.8591	1.794	.0500	2.9091	15.969	3.218
gh slope formed of cleats and	3	2.4948	1.516	.0357	2.5305	12.933	3.213
aulate concrete and riprap. Dec.	4	2.1420	1.248	.0241	2.1661	10.211	3.203
	5	1.6238	.880	.0120	1.6358	6.740	3.222
	6	1.2597	.623	.0060	1.2657	4.548	3.194
	7	1.1419	.515	.0046	1.1465	3.913	3.188
	8	.7196	.288	.0013	.7209	1.945	3.178
	9	.4873	.166	.0004	.4877	1.087	3.192
Series 3—Model A.	1	2.0030	1.124	.0197	2.0187	9.037	3.148
, old Croton dam, 16-foot crest,	2	1.4091	.712	.0078	1.4129	5.308	3.161
ith wire cloth of No. 18 wire,	3	.8675	.366	.0021	.8656	2.527	3.138
sh,a rough slope, as in series 2.	4	.4288	.133	.0003	.4251	.861	3.099
99.	5	.1184	.020	.0000	.1144	.124	3.205

iments with wire cloth over crest, 0.004 foot is deducted from observed depth to for thickness of wire.

Experiments on volume of flow over models of old Croton dam, Cornell University hydraulic laboratory, 1899—Continued.

	Period No.	Observed depth on model dam, in feet.	Mean velocity of approach, in feet per second.	Correction for velocity of approach, in feet.	Corrected head on model dam, in feet.	Discharge over model dam per foot of length, in cubic feet per second.	C_1
1	2	3	4	5	6	7	8
Series 1—Model B. Angular crest, old Croton dam, 16-foot crest, all unplaned plank. Nov. 15, 1899.	1	1.8635	0.973	0.0147	1.8782	9.506	3.695
	2	.9246	.370	.0021	.9267	3.272	3.668
	3	.6419	.219	.0008	.6427	1.870	3.630
	4	.3481	.090	.0001	.3482	.741	3.606
	5	.1787	.034	.0000	.1787	.272	3.601
Series 2—Model B. Angular crest, old Croton dam, 16-foot unplaned plank, crest slope roughened with cleats and stone. Nov. 28, 1899.	1	2.4126	1.298	.0262	2.4388	13.478	3.539
	2	1.5251	.736	.0084	1.5335	6.945	3.657
	3	.9611	.391	.0024	.9635	3.466	3.665
	4	.5157	.162	.0004	.5161	1.369	3.662
	5	.3051	.077	.0001	.3052	.631	3.742
	6	.0890	.012	.0000	.0890	.094	3.540
Series 2—Continued model B. Conditions as in preceding. Nov. 16, 1899.	1	1.8930	.988	.0151	1.9081	9.683	3.674
	2	.9605	.391	.0024	.9629	3.465	3.667
	3	.7028	.251	.0010	.7038	2.165	3.667
	4	.3941	.108	.0002	.3943	.900	3.655
	5	.1952	.039	.0000	.1952	.314	3.641
Series 3—Model B. Angular crest, old Croton dam, wire cloth on crest, rough slope. Nov. 16, 1899.	1	2.0053	1.047	.0170	[a]2.0183	10.385	3.622
	2	.9787	.389	.0024	.9771	3.463	3.586
	3	.7391	.259	.0011	.7362	2.241	3.548
	4	.1785	.032	.0000	.1745	.260	3.567
Series 1—Model C. Round crest, old Croton dam, 12-inch timber on crest, 16 feet long, rough slope. Dec. 1, 1899.	1	1.9941	1.097	.0187	2.0128	9.904	3.468
	2	1.1817	.512	.0040	1.1857	4.211	3.202
	3	.8832	.328	.0017	.8849	2.594	3.116
	4	.6873	.222	.0008	.6881	1.722	3.017
	5	.4986	.141	.0003	.4989	1.065	3.022
	6	.2992	.071	.0001	.2993	.522	3.188
	7	.1177	.019	.0000	.1177	.139	3.450
	8	.0846	.009	.0000	.0846	.067	2.723
Series 1—Continued model C. Conditions as in preceding. Dec. 4, 1899.	1	2.7146	1.632	.0414	2.7560	15.917	3.479
	2	2.4519	1.436	.0320	2.4839	13.629	3.482
	3	1.5566	.774	.0093	1.5659	6.660	3.399
	4	1.1046	.016	.0000	.1046	.112	3.311
	5	.1070	.0165	.0000	.1070	.118	3.371
Series 1—Model D. Angular crest, old Croton dam, 12-inch timber, on 16-foot crest, rough slope. Nov. 16, 1899.	1	1.2390	.495	.0038	1.2428	5.026	3.628
	2	.7885	.249	.0010	.7895	2.415	3.443
	3	.4448	.113	.0002	.4450	1.054	3.551

[a] In experiments with wire cloth over crest, 0.004 foot is deducted from observed depth to compensate for thickness of wire.

ments on volume of flow over models of old Croton dam, Cornell University hydraulic laboratory, 1899—Continued.

	Period No.	Observed depth on model dam, in feet.	Mean velocity of approach, in feet per second.	Correction for velocity of approach, in feet.	Corrected head on model dam, in feet.	Discharge over model dam per foot of length, in cubic feet per second.	C_1
1	2	3	4	5	6	7	8
	1	2.3051	1.154	0.0207	2.3258	11.778	3.321
	2	1.8125	.845	.0111	1.8236	8.214	3.336
Series 1—Model E.	3	1.2278	.507	.0040	1.2318	4.632	3.388
ngular crest, old Croton dam, with-	4	.8598	.313	.0015	.8613	2.744	3.433
mber, but with obstructed channel,	5	.5745	.179	.0005	.5750	1.516	3.477
harp contraction. Nov. 18, 1899.	6	.3245	.078	.0001	.3246	.641	3.466
	7	.1120	.017	.0000	.1120	.133	3.548
	8	.1102	.017	.0000	.1102	.140	3.827
	1	1.4569	.636	.0063	1.4632	5.957	3.366
	2	.9168	.338	.0018	.9186	2.982	3.387
Series 1—Model E, repeated.	3	.6866	.237	.0009	.6875	2.037	3.573
ons as in preceding. Nov. 25, 1899.	4	.4820	.148	.0003	.4823	1.240	3.702
	5	.2811	.071	.0001	.2812	.579	3.883
	6	.1416	.028	.0000	.1416	.226	4.203
	1	2.2927	1.139	.0202	2.3129	[a]11.613	3.302
	2	2.2914	1.138	.0202	2.3116	[b]11.606	3.302
Series 2—Model E.	3	1.1395	.473	.0034	1.1429	4.278	3.501
r crest, old Croton dam, 16 feet long	4	1.1403	.453	.0031	1.1434	[a]4.097	3.351
ut timber, and with slope instead of	5	1.1006	.448	.0031	1.1037	[b]4.034	3.479
edge to upstream end of obstruction.	6	1.1099	.457	.0032	1.1131	4.119	3.507
27, 1899.	7	.4763	.141	.0003	.4766	1.180	3.586
	8	.0233	.031	.0000	.0233	.025	7.029

[a] Trap open. [b] Trap closed.

the experimental weir two similar piezometers, each about one of the width of the channel from the side, were used. Owing e long back slope of some of the model dams, the head was ured 69.75 feet upstream from the crest of the experimental . Readings of all the piezometers were taken at half-minute vals, two and sometimes three observers working at each weir. mean of ten to twenty observations was used to determine the for each period in the experiment. Freeman states that he ders the results of these experiments for heads up to 2.5 feet, ding all sources of errors, as certainly correct within 2 per and probably much closer. In reducing the experiments, the on the experimental weir is corrected by a method comparable that of Francis. Freeman does not give the resulting coefficients ne weir formula, but presents the results in the form of diagrams ing the discharge per foot of crest for the various models. In ccompanying tables the computations have been carried out to

show the coefficients, some errors in the original data having been omitted.

Column 3 shows the observed head on the experimental dam, in feet.

Column 7 shows the computed discharge over the experimental dam, per foot of crest. This was determined by calculating the discharge over the standard weir by means of both the Francis and Bazin formulas, the mean of the two having been used. The result corrected for slight leakage, divided by 16 (the length in feet of the experimental weir model), appears in column 7.

Columns 4 and 5 show the velocity of approach and the corresponding velocity head at the experimental weir. The velocity of approach correction was made by adding directly the velocity head as given to the observed depth on the model dam, this being considered a sufficiently close approximation to the Francis method of correction.

Columns 1 to 7 are taken from the original computations. The coefficient C_1 has been computed from the data in columns 6 and 7 by the formula

$$C_1 = \frac{Q}{H^{\frac{3}{2}}}.$$

Pls. XIX to XXII show the resulting coefficients applicable in the formula here adopted,

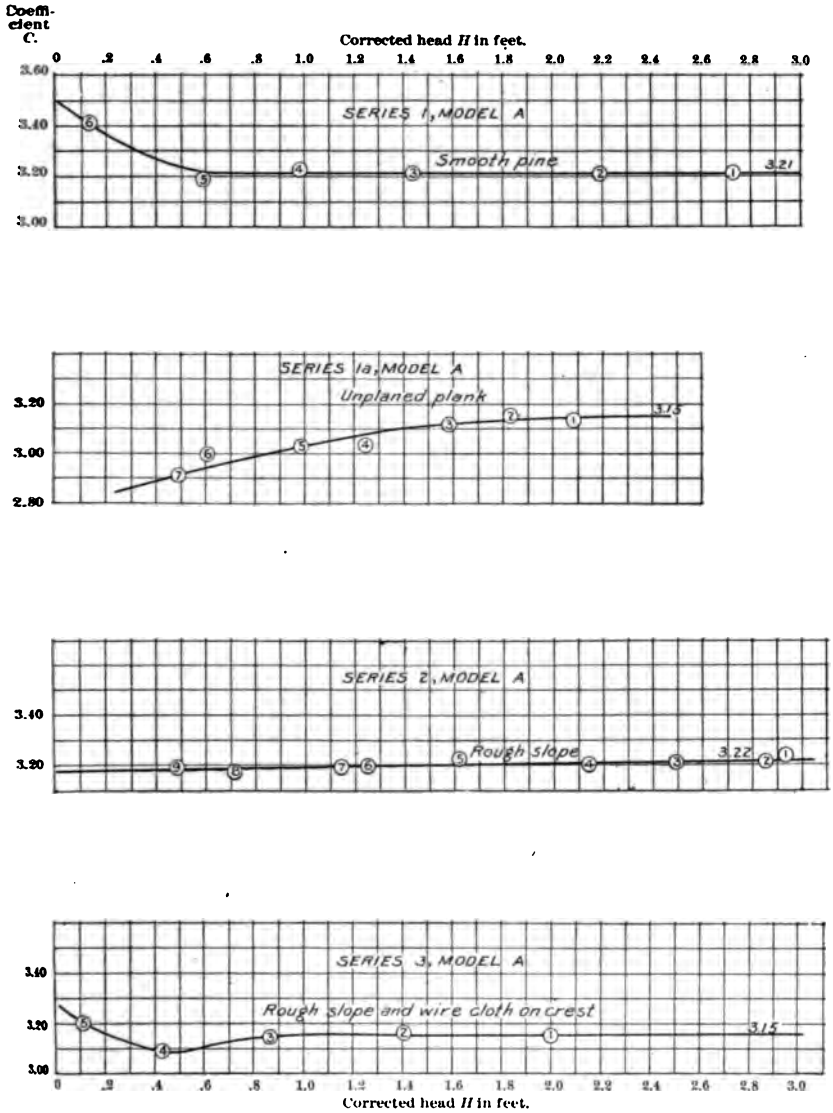
$$Q = C_1 L H^{\frac{3}{2}},$$

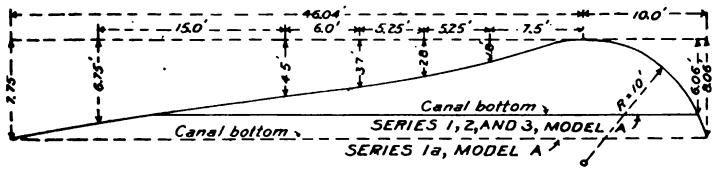
correction for velocity of approach being made by the Francis correction formula or an equivalent method.

These experiments were performed for the specific purpose of determining the discharge over the old Croton dam. They include two main groups: (1) Experiments on round-crested portion of the dam; (2) experiments on the angular-crested portion of the dam. Each group includes series of experiments on: (*a*) Model of smooth-planed pine; (*b*) model of unplaned plank; (*c*) model with cleats and fragments of stone on the upstream slope to simulate the natural back filling; (*d*) model with rough slope and with ¼-inch-mesh wire cloth on crest to simulate cut stone; (*e*) model surmounted by 12-inch-square timber on crest. Experiments were added with a construction to simulate a natural rock ledge lying upstream from the angular portion of the dam.

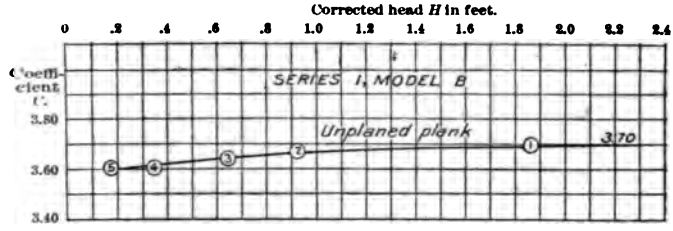
The experiments were abbreviated owing to lateness of season and trouble from air in the gage pipes.

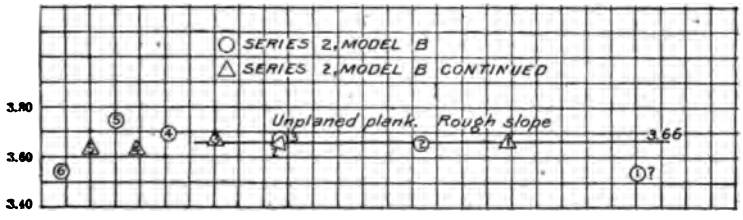
The value of the results is limited by the narrow range of heads covered. The models were of unusual forms, and show some peculiar differences when an attempt is made to compare the results with those of other weirs of similar slopes. The data are of value as showing the effect of various degrees of roughness on the discharge.

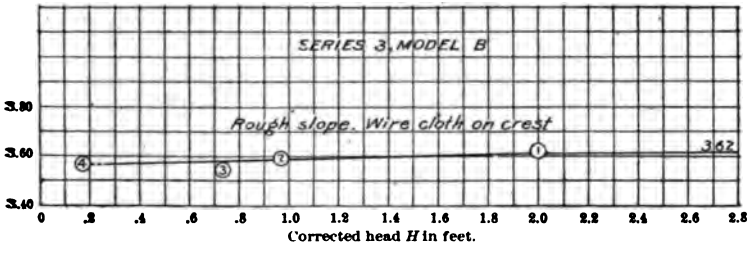


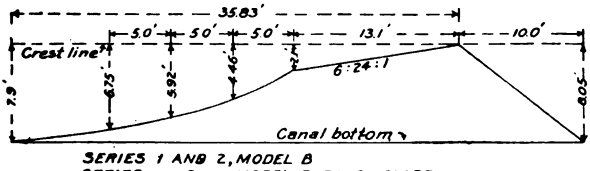


EXPERIMENTS ON ROUND-CRESTED MODELS OF OLD CROTON DAM.



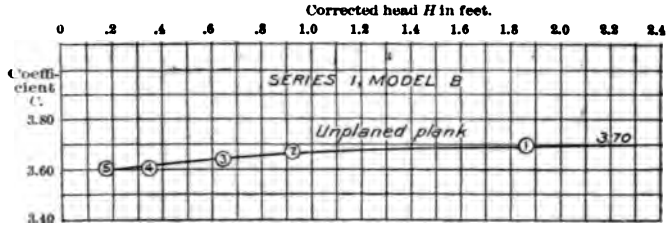


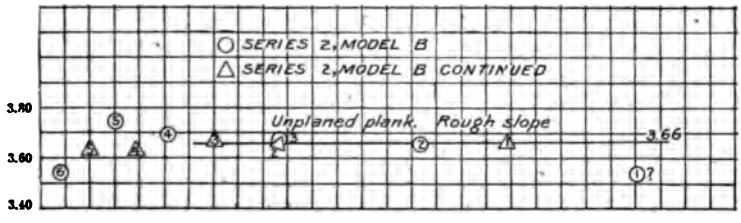


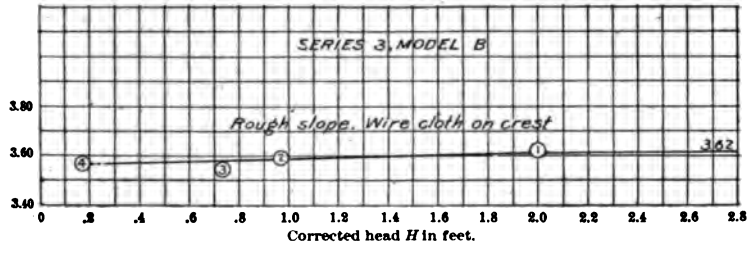


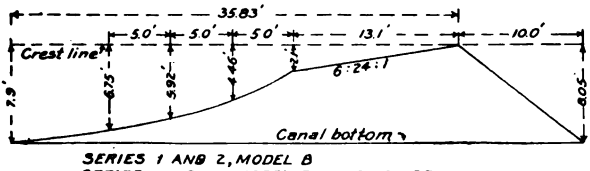
SERIES 1 AND 2, MODEL B
SERIES 3, MODEL B, ROUGH SLOPE

EXPERIMENTS ON ANGULAR-CRESTED MODELS OF OLD CROTON DAM.



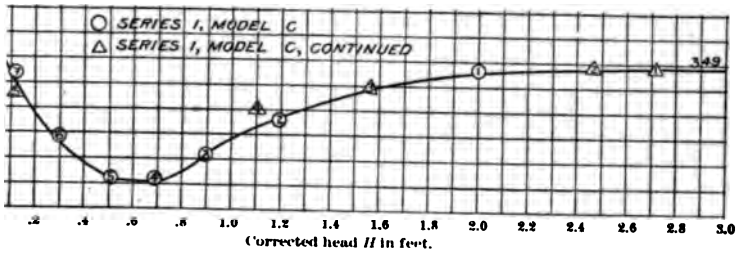


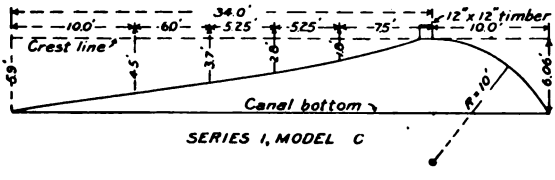


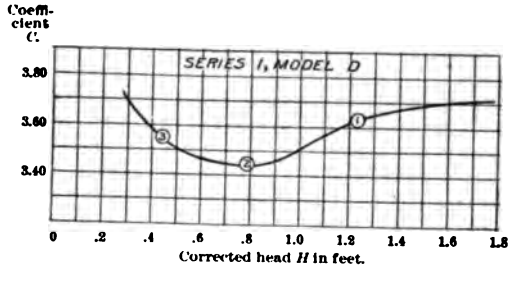


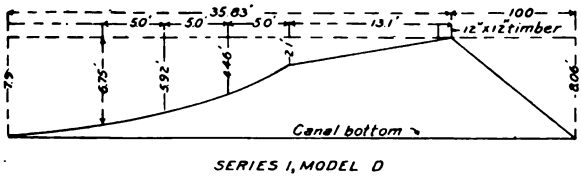
SERIES 1 AND 2, MODEL B
SERIES 3, MODEL B, ROUGH SLOPE

EXPERIMENTS ON ANGULAR-CRESTED MODELS OF OLD CROTON DAM.

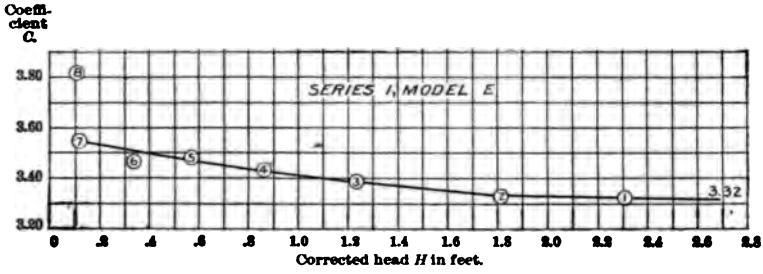


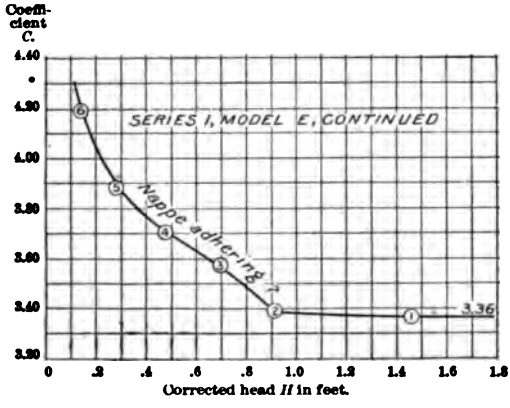


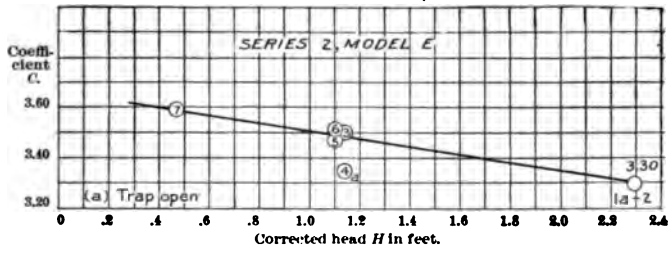


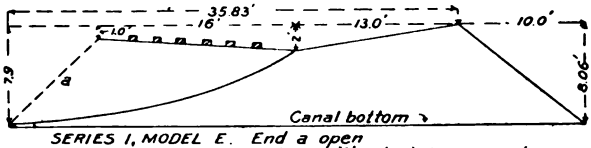


OLD CROTON DAM MODELS WITH CREST TIMBER.



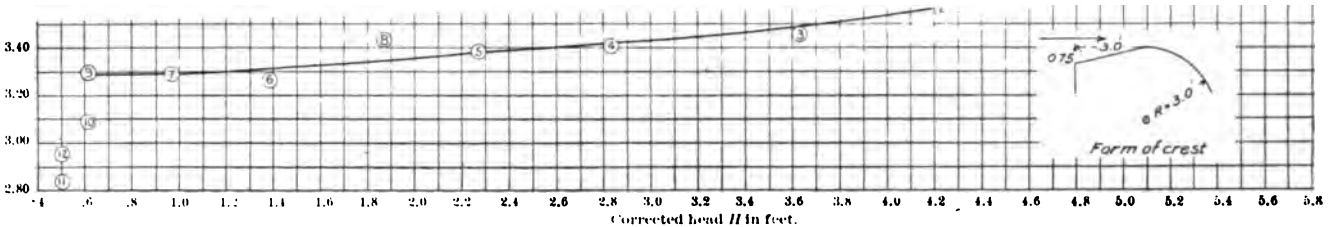




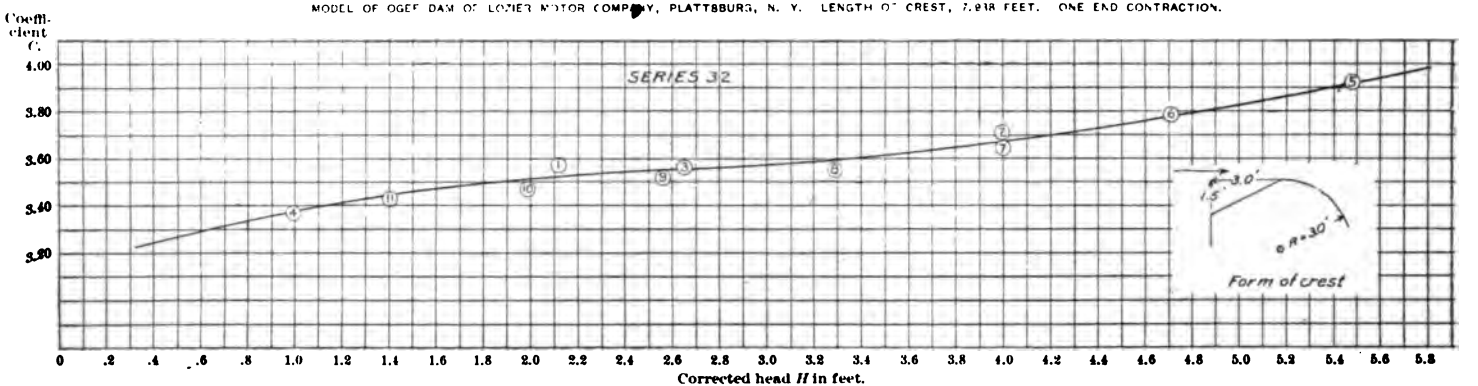


SERIES 1, MODEL E. End a open
SERIES 2. MODEL E End a with sloping approach

ANGULAR CROTON DAM MODEL, WITH CONSTRUCTION TO SIMULATE ROCK LEDGE.

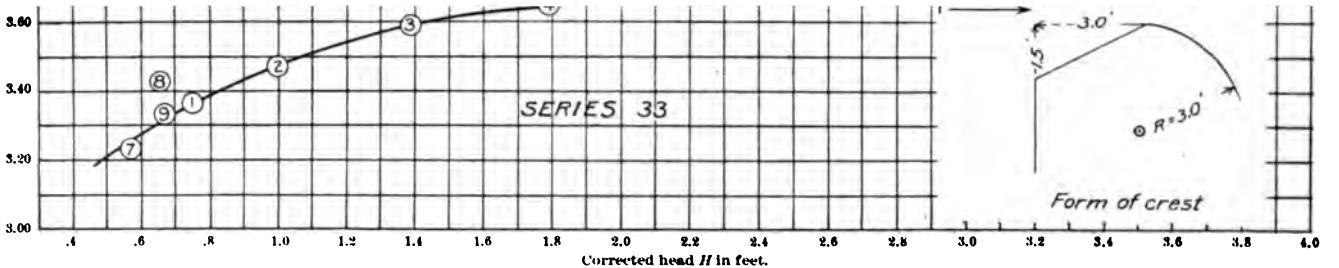


MODEL OF OGEE DAM OF LOZIER MOTOR COMPANY, PLATTSBURG, N. Y. LENGTH OF CREST, 7.918 FEET. ONE END CONTRACTION.

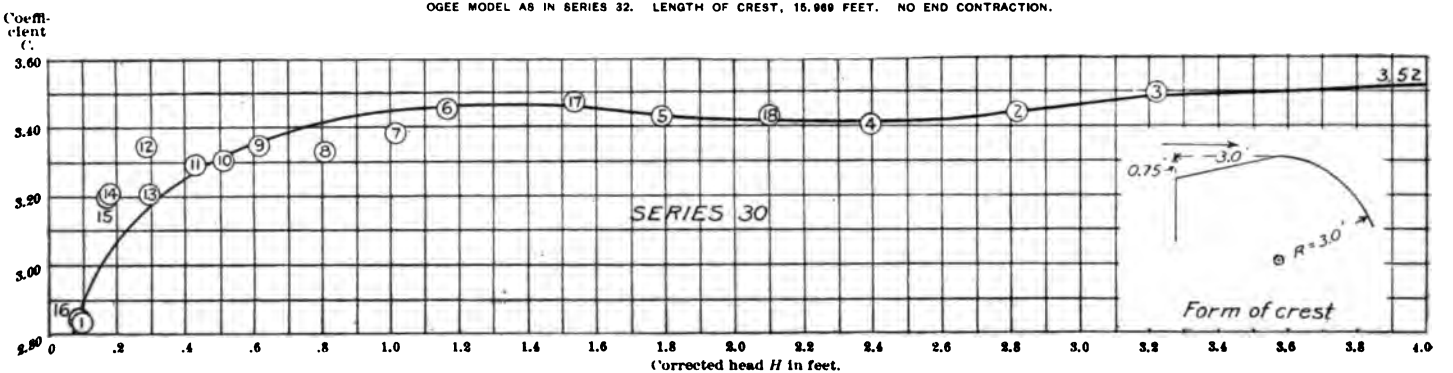


MODEL SIMILAR TO PLATTSBURG DAM, WITH BACK SLOPE MODIFIED. LENGTH OF CREST, 7.979 FEET. ONE END CONTRACTION.

EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.



OGEE MODEL AS IN SERIES 32. LENGTH OF CREST, 15.969 FEET. NO END CONTRACTION.



MODEL OF OGEE DAM OF LOZIER MOTOR COMPANY, PLATTSBURG, N. Y LENGTH OF CREST, 15.969 FEET.

EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.

tates Geological Survey experiments at Cornell University hydraulic laboratory on model of Plattsburg dam—Continued.

). XXXI. Height of weir = P, 11.25 feet; length of weir crest = L, 7.938 feet; width of channel = b, 15.970 feet; height of upstream crest corner, 10.50 feet; width of crest, 3 feet.]

Measured head on experimental weir, in feet.				A = area of section per foot of crest.	v = mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q = discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.	L = effective length of crest weir.
Number of observations.	Maximum.	Minimum.	Mean = D.			$H^{\frac{3}{2}}$	H			
2	3	4	5	6	7	8	9	10	11	12
25	5.1003	4.9273	5.0014	259.535	1.201	11.257	5.023	41.925	3.724	7.436
15	4.2873	4.1693	4.2214	247.078	.945	8.714	4.235	31.086	3.567	7.514
44	3.6893	3.5253	3.6191	507.460	.356	6.890	3.621	23.868	3.464	7.580
21	2.8213	2.8003	2.8185	224.674	.551	4.743	2.823	16.170	3.409	7.656
39	2.2713	2.2623	2.2696	215.780	.412	3.425	2.273	11.545	3.377	7.711
40	1.3903	1.3813	1.3861	201.998	.206	1.633	1.387	5.338	3.269	7.799
26	.9673	.9653	.9663	195.094	.125	.950	.966	3.120	3.284	7.841
25	1.8793	1.8723	1.8749	209.605	.326	2.570	1.876	8.814	3.429	7.750
30	.6093	.6083	.6087	189.383	.065	.475	.609	1.562	3.288	7.877
18	.6073	.6063	.6063	189.345	.060	.472	.606	1.456	3.083	7.877
40	.3023	.2993	.3017	184.171	.020	.165	.301	.469	2.838	7.908
19	.3003	.2993	.3017	184.481	.021	.166	.302	.490	2.956	7.908

). XXXII. Height of weir = P, 11.25 feet; length of weir crest = L, 7.979 feet; width of channel = b, 15.970 feet; height of upstream crest corner, 9.75 feet; width of crest, 3 feet.]

10	2.1193	2.0943	2.1173	213.476	0.004	3.081	2.117	11.029	3.580	7.767
23	4.0343	3.9883	4.0053	243.627	.928	8.055	4.018	29.846	3.706	7.577
26	2.6693	2.6333	2.6469	221.934	.535	4.317	2.651	15.398	3.567	7.714
34	.9953	.9923	.9942	195.540	.135	.992	.994	3.342	3.370	7.880
32	5.5543	5.2983	5.4712	267.038	1.404	12.855	5.487	50.440	3.924	7.430
27	4.7343	4.6443	4.6947	254.637	1.141	10.235	4.714	38.704	3.782	7.508
27	4.0173	3.9883	4.0007	240.808	.925	8.040	4.013	29.395	3.656	7.578
28	3.3053	3.2673	3.2890	232.188	.701	5.984	3.296	21.278	3.556	7.649
31	2.5863	2.5193	2.5596	220.539	.506	4.104	2.564	14.160	3.524	7.723
28	1.9913	1.9693	1.9801	211.285	.357	2.790	1.982	9.686	3.471	7.781
53	1.4113	1.4023	1.4015	202.044	.221	1.661	1.402	5.704	3.434	7.839

puted in cubic meters per second and has been reduced to cubic feet per second, the discharge table being as follows:

Discharge over standard weir at different heads.

Head, in meters.	Q in cubic meters, per second.	Head, in meters.	Q in cubic meters, per second.
0.05	0.111863	0.60	4.21730
.10	.296230	.70	5.34459
.15	.53207	.80	6.57096
.20	.81166	.90	7.89078
.25	1.12871	1.00	9.30650
.30	1.48032	1.10	10.81066
.40	2.27850	1.20	12.40420
.50	3.19350		

The discharge curve for the standard weir has also been carefully checked by comparing the depth flowing over with that on a similar weir, using the formula and method of determining the head adopted by Fteley and Stearns; it has also been checked by float and current-meter measurements, and for lower heads by means of volumetric measurement of the discharge in the gaging channel, so that it is believed that the discharge in these experiments is known within 1 or 2 per cent of error as a maximum.

The work of calibrating the standard weir had been accomplished by Professor Williams and his assistants before the experiments of the United States Geological Survey were taken up, so that somewhat more certainty attaches to the results of these later experiments than to earlier experiments made before the standard-weir discharge had been thoroughly checked.

It was the wish of the Geological Survey that the conditions at the experimental weirs should conform to those actually existing at dams which are utilized as weirs, in connection with the stream-gaging operations. In such cases it is often impracticable to utilize gage pits of the form adopted by Bazin or to use piezometer or hook gages. The usual method is to read the depth directly on a graduated vertical scale or measure the distance to water surface from a suitable bench mark. The method adopted in the weir experiments consisted of reading directly the distance to water surface from bench marks located above the central line of the channel. The readings were taken by means of a needle-pointed plumb bob attached to a steel tape forming a point gage, readings being taken to thousandths of a foot.

Two gages were used, one located 10.3 feet upstream from the crest and another 16.059 feet upstream. In series XXXV and following, for the higher heads, the readings of the upstream tape were used. For heads where no general difference was apparent the average of the read[illegible] the two tapes was taken. In general, the

ce curve did not perceptibly affect the reading of the gage nearest veir for depths below 3 feet. The readings of the tapes were ked from time to time by observations with hook gages, thus pracy eliminating the effect of temperature on the tapes. Observa- of the head were usually taken at intervals of thirty seconds. t care was used to maintain a uniform regimen of flow during experimental period, and the variations of head were very slight. character of the observations is illustrated by the following data ı from the experiments:

Readings of tapes to determine head at experimental weir.

Series XL. Period 10. Date 6, 22, 03.		Series XLI. Period 5. Date 6, 23, 03.	
Time.	Readings.	Time.	Readings.
h. m. s.		*h. m. s.*	
12 37 40	42.681	1 34 30	43.633
	.681		.632
	.680		.633
	.681		.630
12 39 00	.682		.630
12 52 30	42.680		.633
	.681		.635
	.680		.635
	.679		.634
12 54 30	.680		.633
Mean	42.6805		.630
			.635
			.630
			.635
			.635
			.633
			.630
			.630
			.630
			.630
			.634
			.630
			.628
			.630
			.632
			.628
		1 51 20	.631
		Mean	43.6317

Series XLIII. Period 3. Date 6, 26, 03.	
Time.	Readings.
h. m. s.	
12 36 20	2.305
	.302
	.302
	.302
	.301
	.302
	.301
	.300
12 42 10	.300
Mean	2.3015

For the lower heads the discharge over the experimental weir was volumetrically determined by measuring the rise of water in the canal as follows:

List of experimental periods for which the discharge was volumetrically determined.

Series.	Periods.	Series.	Periods.	Series.	Periods.
30	1, 13, 14, 16	39	1	44	1, 2, 3
31	10, 11	40	1, 2	45	1, 2, 3
34	1, 9, 10	41	13, 14	46	1, 2, 3
37	5 [a]	43	1, 2, 3	47	1, 2, 3
38	5, 6	43 [a]	1, 2, 3, 4		

United States Geological Survey experiments at Cornell University hydraulic laboratory on model of Plattsburg dam.

[Series No. XXX. Height of weir=P, 11.25 feet; length of weir crest=L, 15.969 feet; width of channel=b, 15.970 feet; height of upstream crest corner, 10.50 feet; crest width, 3 feet.]

No.	Measured head on experimental weir, in feet.				A= area of section per foot of crest.	v= mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q=discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
	Number of observations.	Maximum.	Minimum.	Mean =D.			$H^{\frac{3}{2}}$	H		
1	2	3	4	5	6	7	8	9	10	11
1	92	0.0993	0.0818	0.096	11.347	0.007	0.030	0.096	0.084	2.835
2	31	.7993	.7863	2.790	14.041	1.155	4.710	2.810	16.218	3.443
3	19	3.1993	3.1473	3.187	14.438	1.396	5.766	3.216	20.152	3.495
4	26	2.3993	2.3473	2.384	13.635	.926	3.710	2.396	12.631	3.405
5	29	1.7973	1.7853	1.793	13.043	.636	2.412	1.799	8.282	3.433
6	27	1.1803	1.1723	1.174	12.425	.354	1.274	1.176	4.399	3.454
7	18	1.0133	1.0073	1.010	12.260	.280	1.016	1.011	3.435	3.381
8	16	.8043	.8003	.802	12.053	.200	.719	.803	2.409	3.348
9	34	.6143	.6113	.613	11.864	.136	.481	.614	1.608	3.345
10	24	.5083	.5073	.508	11.758	.102	.362	.508	1.195	3.302
11	15	.4283	.4263	.427	11.678	.079	.280	.428	.921	3.296
12	20	.2943	.2903	.291	11.542	.046	.157	.291	.526	3.344
13	32	.2933	.2903	.292	11.543	.044	.158	.292	.506	3.209
14	21	.1783	.1763	.178	11.427	.021	.075	.178	.240	3.202
15	24	.1793	.1733	.179	11.429	.020	.076	.179	.226	2.976
16	40	.0893	.0893	.089	11.340	.007	.027	.089	.076	2.841
17	26	1.5373	1.5303	1.532	12.783	.517	1.904	1.535	6.607	3.471
18	25	2.1033	2.0843	2.094	13.345	.793	3.051	2.104	10.576	3.466

es Geological Survey experiments at Cornell University hydraulic laboratory on model of Chambly dam.

XXXV. Height of weir=P, 11.25 feet; length of weir crest=L, 15.969 feet; width of l=b, 15.970 feet; height of upstream crest corner, 10.25 feet; width of crest 4.5 feet.]

Measured head on experimental weir, in feet.				A= area of section per foot of crest.	v= mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q=discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
Number of observations.	Maximum.	Minimum.	Mean =D.			$H^{\frac{3}{2}}$	H		
2	3	4	5	6	7	8	9	10	11
64	2.5503	2.5463	0.549	11.799	0.110	0.407	0.549	1.297	3.189
55	1.0103	1.0063	1.008	12.259	.272	1.014	1.009	3.331	3.285
40	1.5643	1.5523	1.559	12.810	.511	1.954	1.563	6.548	3.352
40	2.0273	2.0133	2.021	13.272	.744	2.890	2.029	9.874	3.416
38	1.7513	1.7303	1.739	12.990	.602	2.304	1.744	7.816	3.392
45	1.2673	1.2583	1.262	12.513	.379	1.422	1.265	4.747	3.337
41	.7593	.7543	.757	12.008	.176	.660	.758	2.114	3.205
43	.4453	.4373	.441	11.692	.079	.293	.441	.919	3.132
20	.3043	.3003	.302	11.553	.045	.166	.302	.525	3.159
18	3.7303	3.7063	3.755	15.006	1.740	7.403	3.798	26.114	3.528
17	3.2193	3.1813	3.195	14.446	1.406	5.789	3.224	20.319	3.510
17	3.0023	2.9873	2.987	14.238	1.283	5.224	3.011	18.267	3.496
18	2.6743	2.6643	2.642	13.892	1.077	4.334	2.658	14.963	3.452
23	2.3533	2.3283	2.317	13.568	.901	3.555	2.330	12.221	3.438
22	1.4923	1.4873	1.463	12.713	.478	1.775	1.466	6.072	3.420
37	.2103	.2093	.184	11.435	.023	.079	.184	.258	3.260
25	.3913	.3903	.391	11.642	.065	.245	.391	.758	3.096
17	.3313	.3313	.331	11.582	.053	.191	.331	.609	3.194
24	.2523	.2523	.253	11.504	.035	.127	.253	.404	3.258
21	.2203	.2193	.221	11.472	.028	.104	.221	.325	3.120
24	.1843	.1833	.183	11.434	.021	.078	.183	.238	3.039
19	.1323	.1313	.132	11.383	.012	.048	.132	.136	2.826
20	.0823	.0823	.083	11.334	.007	.024	.083	.079	3.321

XXVI. Height of weir =P, 11.25 feet; length of weir crest L, 15.969 feet; width of chan- 70 feet; height of upstream crest corner, 10.50 feet; width of crest, 4.5 feet, with 4 inches ter round.]

18	2.7653	2.6913	2.741	13.991	1.185	4.594	2.764	16.586	3.610
18	2.3513	2.2913	2.316	13.567	.936	3.558	2.330	12.698	3.569
30	2.9373	2.8923	1.915	13.166	.702	2.666	1.923	9.243	3.467
23	1.5173	1.4993	1.507	12.758	.501	1.857	1.511	6.390	3.441
21	1.1143	1.1013	1.111	12.361	.320	1.173	1.112	3.950	3.367
19	.7553	.7493	.753	12.004	.177	.654	.753	2.123	3.248
22	.4943	.4903	.492	11.743	.095	.345	.492	1.113	3.221

United States Geological Survey experiments at Cornell University hydraulic laboratory on model of Plattsburg dam—Continued.

[Series No. XXXIII. Height of weir=P, 11.25 feet; length of weir crest=L, 15.969 feet; width of channel=b, 15.970 feet; height of upstream crest corner, 9.79 feet; width of crest, 3 feet.]

No.	Measured head on experimental weir, in feet.				A= area of section per foot of crest.	v= mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q=discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
	Number of observations.	Maximum.	Minimum.	Mean =D.			$H^{\frac{3}{2}}$	H		
1	2	3	4	5	6	7	8	9	10	11
1	15	0.7563	0.7493	0.752	12.003	0.183	0.653	0.753	2.197	3.363
2	43	.9973	.9873	.992	12.243	.281	.990	.993	3.439	3.473
3	29	1.3963	1.3903	1.394	12.644	.468	1.651	1.397	5.913	3.580
4	33	1.7893	1.7803	1.784	13.034	.671	2.396	1.790	8.747	3.651
5	23	2.3733	2.3363	2.352	13.603	.990	3.641	2.367	13.464	3.698
6	24	2.6683	2.6503	2.660	13.910	1.170	4.387	2.680	16.272	3.709
7	52	.5593	.5493	.553	11.803	1.183	.432	.572	1.397	3.232
8	42	.6603	.6493	.653	11.904	.152	.528	.654	1.808	3.422
9	12	.6804	.6783	.679	11.930	.156	.560	.680	1.866	3.330

[Series No. XXXIV. Height of weir=P, 11.25 feet; length of weir crest=L, 15.969 feet; width of channel=b, 15.970 feet; height of upstream crest corner, 8.37 feet; width of crest, 3 feet.]

1	16	0.6453	0.6383	0.641	11.891	0.137	0.513	0.641	1.632	3.182
2	16	.6423	.6383	.640	11.891	.141	.513	.640	1.680	3.276
3	21	2.0253	2.0043	2.015	13.266	.816	2.882	2.025	10.826	3.756
4	19	1.6303	1.6203	1.628	12.878	.592	2.086	1.633	7.627	3.656
5	19	1.2333	1.2293	1.232	12.483	.391	1.371	1.235	4.877	3.555
6	14	.9523	.9483	.950	12.201	.261	.927	.951	3.185	3.434
7	20	.4013	.3983	.400	11.650	.070	.253	.400	.815	3.225
8	10	.6243	.6243	.624	11.875	.136	.493	.625	1.613	3.269
9	32	.2243	.2203	.222	11.473	.029	.105	.222	.328	3.133
10	39	.1103	.1093	.110	11.360	.009	.036	.110	.100	2.777
11	14	5.0963	5.0793	3.089	14.340	1.509	5.515	3.122	21.636	3.923
12	25	2.7763	2.7263	2.749	14.000	1.258	4.615	2.772	17.612	3.816
13	31	2.4383	2.3963	2.421	13.672	1.051	3.805	2.437	14.374	3.778
14	25	2.8013	2.7963	.800	12.050	.194	.716	.800	2.341	3.271

ited States Geological Survey experiments at Cornell University hydraulic laboratory on model of Chambly dam.

ries No. XXXV. Height of weir=P, 11.25 feet; length of weir crest=L, 15.969 feet; width of channel=b, 15.970 feet; height of upstream crest corner, 10.25 feet; width of crest 4.5 feet.]

No.	Measured head on experimental weir, in feet.				A= area of section per foot of crest.	v= mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q=discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
	Number of observations.	Maximum.	Minimum.	Mean =D.			$H^{\frac{3}{2}}$	H		
1	2	3	4	5	6	7	8	9	10	11
1	64	2.5503	2.5463	0.549	11.799	0.110	0.407	0.549	1.297	3.189
2	55	1.0103	1.0063	1.008	12.259	.272	1.014	1.009	3.331	3.285
3	40	1.5643	1.5523	1.559	12.810	.511	1.954	1.563	6.548	3.352
4	40	2.0273	2.0133	2.021	13.272	.744	2.890	2.029	9.874	3.416
5	38	1.7513	1.7303	1.739	12.990	.602	2.304	1.744	7.816	3.392
6	45	1.2673	1.2583	1.262	12.513	.379	1.422	1.265	4.747	3.337
7	41	.7593	.7543	.757	12.008	.176	.660	.758	2.114	3.205
8	43	.4453	.4373	.441	11.692	.079	.293	.441	.919	3.132
9	20	.3043	.3003	.302	11.553	.045	.166	.302	.525	3.159
11	18	3.7303	3.7063	3.755	15.006	1.740	7.403	3.798	26.114	3.528
12	17	3.2193	3.1813	3.195	14.446	1.406	5.789	3.224	20.319	3.510
13	17	3.0023	2.9873	2.987	14.238	1.283	5.224	3.011	18.267	3.496
14	18	2.6743	2.6643	2.642	13.892	1.077	4.334	2.658	14.963	3.452
15	23	2.3533	2.3283	2.317	13.568	.901	3.555	2.330	12.221	3.438
16	22	1.4923	1.4873	1.463	12.713	.478	1.775	1.466	6.072	3.420
17	37	.2103	.2093	.184	11.435	.023	.079	.184	.258	3.260
18	25	.3913	.3903	.391	11.642	.065	.245	.391	.758	3.096
19	17	.3313	.3313	.331	11.582	.053	.191	.331	.609	3.194
20	24	.2523	.2523	.253	11.504	.035	.127	.253	.404	3.258
21	21	.2203	.2193	.221	11.472	.028	.104	.221	.325	3.120
22	24	.1843	.1833	.183	11.434	.021	.078	.183	.238	3.039
23	19	.1323	.1313	.132	11.383	.012	.048	.132	.136	2.826
24	20	.0823	.0823	.083	11.334	.007	.024	.083	.079	3.321

Series No. XXXVI. Height of weir P, 11.25 feet; length of weir crest L, 15.969 feet; width of channel=b, 15.970 feet; height of upstream crest corner, 10.50 feet; width of crest, 4.5 feet, with 4 inches radius quarter round.]

1	18	2.7653	2.6913	2.741	13.991	1.185	4.594	2.764	16.586	3.610
2	18	2.3513	2.2913	2.316	13.567	.936	3.558	2.330	12.698	3.569
3	30	2.9373	2.8923	1.915	13.166	.702	2.666	1.923	9.243	3.467
4	23	1.5173	1.4993	1.507	12.758	.501	1.857	1.511	6.390	3.441
5	21	1.1143	1.1013	1.111	12.361	.320	1.173	1.112	3.950	3.367
6	19	.7553	.7493	.753	12.004	.177	.654	.753	2.123	3.248
7	22	.4943	.4903	.492	11.743	.095	.345	.492	1.113	3.221

United States Geological Survey experiments at Cornell hydraulic laboratory on model Dolgeville dam with injured apron.

[Series No. XXXVII. Height of weir=P, 11.25 feet; length of weir crest=L, 15.969 feet; width channel=b, 15.970 feet; height of upstream crest corner, 10.25 feet; width of crest, 6 feet.]

No.	Measured head on experimental weir, in feet.				A= area of section per foot of crest.	v= mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q=discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
	Number of observations.	Maximum.	Minimum.	Mean= D.			$H^{\frac{3}{2}}$	H		
1	2	3	4	5	6	7	8	9	10	11
1	30	0.9203	0.9113	0.916	12.166	0.251	0.878	0.917	3.049	3.474
2	35	3.5613	3.4233	3.565	14.816	1.535	6.828	3.599	22.744	3.331
3	28	2.9123	2.8573	2.927	14.178	1.170	5.060	2.947	16.593	3.279
4	52	2.3293	2.2903	2.324	13.574	.906	3.570	2.336	12.297	3.444
5	59	1.6413	1.6213	1.635	12.885	.585	2.100	1.640	7.544	3.593
5a	41	1.3973	1.3923	.415	11.666	.069	.267	.415	.810	3.029

United States Geological Survey experiments at Cornell hydraulic laboratory on model of Dolgeville dam.

[Series No. XXXVIII. Height of weir=P, 11.25 feet; length of weir crest=L, 15.969 feet; width of channel=b, 15.970 feet; height of upstream crest corner, 10.25 feet; width of crest, 600 feet.]

No.	Measured head on experimental weir, in feet.				A= area of section per foot of crest.	v= mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q=discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
	Number of observations.	Maximum.	Minimum.	Mean= D.			$H^{\frac{3}{2}}$	H		
1	2	3	4	5	6	7	8	9	10	11
1	32	0.3973	0.3913	0.395	11.646	0.068	0.249	0.396	0.790	3.176
2	36	1.6843	1.6713	1.689	12.940	.605	2.206	1.695	7.826	3.548
3	25	1.1143	1.1093	1.112	12.362	.333	1.175	1.114	4.113	3.501
4	32	.7513	.7473	.749	12.000	.185	.649	.750	2.223	3.426
5	34	.5093	.5083	.504	11.754	.101	.358	.504	1.186	3.310
6	24	.2173	.2113	.209	11.460	.026	.096	.209	.294	3.081
7	27	3.4726	3.4586	3.470	14.721	1.466	6.551	3.501	21.583	3.295
8	34	3.1176	3.0806	3.100	14.351	1.271	5.521	3.124	18.238	3.303
9	29	2.6176	2.5926	2.605	13.856	1.019	4.243	2.621	14.124	3.329
10	30	2.2096	2.1806	2.198	13.449	.846	3.283	2.209	11.381	3.467
11	28	1.9306	1.8156	1.920	13.171	.726	2.677	1.928	9.558	3.570
12	28	1.5286	1.5106	1.517	12.768	.514	1.872	1.519	6.557	3.503

[Series No. XXXIX. Height of weir=P, 11.25 feet; length of weir crest=L, 15.969 feet; width channel=b, 15.700 feet; height of upstream crest corner, 10.25 feet; width of crest, 6 feet.]

1	26	0.6883	0.6793	0.683	11.934	0.170	0.565	0.684	2.027	3.586
2				.683	11.934	.167	.565	.684	1.995	3.530
3	22	.4183	.4153	.418	11.668	.081	.270	.418	.944	3.497
4	33	3.9806	3.9206	3.943	15.194	1.721	7.956	3.985	26.150	3.287
5	24	3.1506	3.1366	3.145	14.396	1.280	5.642	3.169	18.431	3.266
6	23	2.5066	2.4806	2.488	13.739	.966	3.958	2.502	13.268	3.352
7	36	1.8986	1.8756	1.884	13.135	.699	2.601	1.891	9.186	3.532
8	32	1.2716	1.2626	1.268	12.518	.401	1.432	1.270	5.025	3.509
9	39	.8286	.8206	.826	12.077	.218	.752	.827	2.639	3.494
10	32	.5626	.5606	.561	11.811	.125	.420	.561	1.481	3.526

l States Geological Survey experiments at Cornell hydraulic laboratory on model of flat-top weirs with vertical faces.

[No. XL. Height of weir = P, 11.25 feet; length of weir crest = L, 15.969 feet; width of channel = b, 15.970 feet; width of broad crest, 0.479 foot; nappe aerated.]

No.	Measured head on experimental weir, in feet.				A = area of section per foot of crest.	v = mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q = discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
	Number of observations.	Maximum.	Minimum.	Mean = D.			$H^{\frac{3}{2}}$	H		
1	2	3	4	5	6	7	8	9	10	11
1	19	0.6343	0.6293	0.631	11.882	0.133	0.502	0.632	1.580	3.148
2	17	.2643	.2593	.260	11.511	.030	.133	.260	.343	2.584
3	18	.2613	.2513	.264	11.515	.033	.136	.264	.380	2.794
4	30	.1216	.1206	.124	11.375	.011	.044	.124	.129	2.943
5	33	1.9916	1.9816	1.989	13.238	.710	2.821	1.996	9.401	3.332
6	36	1.6256	1.6106	1.618	12.868	.530	2.065	1.622	6.819	3.301
7	26	1.2556	1.2496	1.256	12.507	.377	1.412	1.259	4.713	3.338
8	21	.9756	.9706	.977	12.228	.262	.967	.978	3.209	3.318
9	21	.8213	.8163	.820	12.070	.204	.743	.820	2.469	3.325
10	10	.6513	.6493	.650	11.900	.139	.524	.650	1.654	3.154
11	10	.4503	.4483	.449	11.700	.074	.301	.449	.867	2.881

[No. XLI. Height of weir = P, 11.25 feet; length of weir crest = L, 15.969 feet; width of channel = b, 15.970 feet; width of broad crest, 1.646 feet; nappe partly aerated.]

1	25	3.8606	3.8256	3.842	15.092	1.692	7.651	3.883	25.531	3.337
2	25	3.1906	3.1666	3.177	14.428	1.317	5.730	3.202	18.995	3.315
3	26	2.6906	2.6656	2.674	13.925	1.050	4.413	2.690	14.624	3.314
4	31	2.0306	2.0116	2.022	13.272	.680	2.889	2.028	9.021	3.123
5	28	1.6043	1.5973	1.601	12.852	.462	2.032	1.604	5.936	2.922
6	27	1.2373	1.2293	1.233	12.484	.307	1.372	1.234	3.835	2.796
7	25	.9443	.9393	.942	12.192	.203	.915	.942	2.476	2.706
8	34	.6733	.6693	.671	11.922	.128	.575	.692	1.472	2.560
9	30	.4893	.4873	.488	11.739	.078	.341	.488	.910	2.669
10	18	.3303	.3293	.330	11.581	.045	.190	.330	.520	2.742
11	34	.2113	.2093	.210	11.461	.024	.096	.210	.272	2.827
12	.....	.....	.....	.122	11.373	.011	.043	.122	.130	3.047
13	22	.1253	.1213	.788	12.038	.153	.699	.788	1.840	2.631
14	20	.4206	.4136	.417	11.668	.064	.270	.417	.750	2.782
15	44	.4206	.4126	.417	11.668	.065	.270	.417	.759	2.815

[No. XLII. Height of weir = P, 11.25 feet; length of weir crest = L, 15.969 feet; width of channel = b, 15.970 feet; width of broad crest, 12.239 feet; nappe partly aerated.]

1	33	0.1706	0.1626	0.168	11.418	0.016	0.069	0.168	0.180	2.611
2	32	4.3706	4.3416	4.353	15.604	1.584	9.196	4.389	24.716	2.688
3	26	3.8316	3.8006	3.809	15.060	1.321	7.510	3.835	19.896	2.649
4	38	3.0446	3.0256	3.032	14.283	.971	5.317	3.046	13.876	2.610
5	32	3.7356	3.7186	1.728	12.979	.467	2.278	1.732	6.066	2.663
6	29	3.5856	3.5776	2.580	13.831	.787	4.166	2.589	10.882	2.612
7	38	3.3966	3.3806	3.387	14.638	1.130	6.285	3.406	16.535	2.631
8	27	2.2506	2.2406	2.243	13.494	.657	3.373	2.249	8.870	2.629
9	34	1.4706	1.4526	1.449	12.700	.369	1.748	1.451	4.682	2.701
10	22	1.0986	1.0906	1.096	12.347	.253	1.149	1.097	3.129	2.723
11	36	.6406	.6376	.639	11.890	.116	.511	.639	1.375	2.689
12	28	.6126	.6106	.611	11.862	.109	.478	.611	1.290	2.700

United States Geological Survey experiments at Cornell hydraulic laboratory on model of flat-top weirs with vertical faces—Continued.

[Series No. XLIII. Height of weir = P, 11.25 feet; length of weir crest = L, 15.969 feet; width of channel = b, 15.970 feet; width of broad crest, 16.302 feet; surface somewhat rough; nappe partly aerated.]

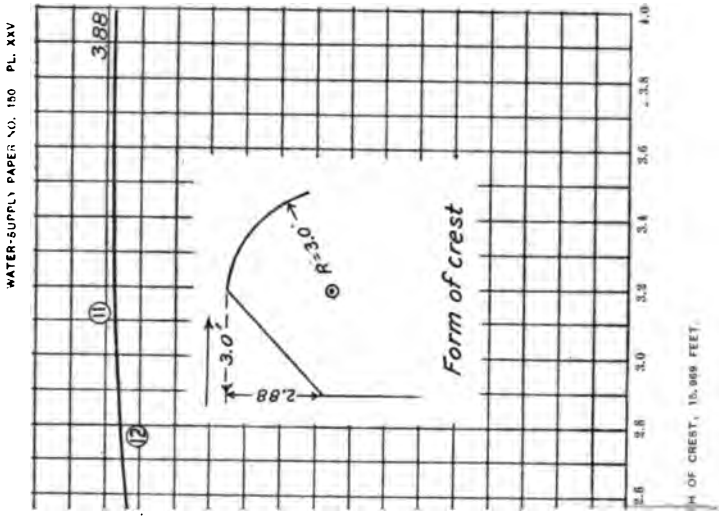
No.	Measured head on experimental weir, in feet.				A = area of section per foot of crest.	v = mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q = discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
	Number of observations.	Maximum.	Minimum.	Mean = D.			$H^{\frac{3}{2}}$	H		
1	2	3	4	5	6	7	8	9	10	11
1	12	0.8536	0.8506	0.851	12.102	0.168	0.786	0.852	2.027	2.579
2	12	.4496	.4426	.447	11.698	.069	.299	.447	.811	2.713
3	10	.3246	.3106	.312	11.563	.040	.174	.312	.468	2.684
4	26	.6936	.6856	.689	11.940	.129	.573	.690	1.544	2.696
5	33	4.4506	4.4176	4.432	15.683	1.595	9.449	4.469	25.011	2.647
6	27	3.6806	3.6306	3.661	14.912	1.251	7.076	3.686	18.657	2.637
7	34	2.9426	2.9306	2.935	14.186	.930	5.062	2.948	13.200	2.608
8	30	2.3626	2.3586	2.360	13.611	.706	3.644	2.368	9.607	2.637
9	23	1.8956	1.8866	1.890	13.141	.520	2.607	1.894	6.841	2.624
10	25	1.4826	1.4756	1.480	12.731	.374	1.804	1.482	4.767	2.531
11	26	1.2086	1.2026	1.206	12.457	.282	1.327	1.208	3.520	2.652

[Series No. XLIIIa. Height of weir = P, 11.25 feet; length of weir crest = L, 15.969 feet; width of channel = b, 15.970 feet; width of broad crest, 16.302 feet; smooth planed surface.]

1	19	0.3626	0.3596	0.361	11.612	0.050	0.217	0.361	0.576	2.653
2	20	.2496	.2426	.246	11.497	.026	.122	.246	.305	2.494
3	44	.1686	.1646	.167	11.418	.013	.068	.167	.153	2.240
4	16	.9906	.9846	.986	12.236	.214	.980	.986	2.618	2.673
5	28	.9856	.9776	.981	12.232	.210	.973	.982	2.568	2.638
6	23	.7886	.7826	.786	12.036	.153	.697	.786	1.847	2.651
7	31	.6226	.6206	.621	11.872	.110	.490	.622	1.309	2.670
8	21	.4976	.4946	.496	11.747	.080	.350	.496	.945	2.704
9	25	.3926	.3906	.392	11.643	.058	.246	.392	.670	2.728
10	31	.2806	.2786	.280	11.530	.036	.148	.280	.421	2.848
11	28	.1606	.1606	.161	11.411	.016	.064	.161	.184	2.851
12	24	.0776	.0756	.077	11.327	.006	.021	.077	.066	3.127

[Series No. XLIV. Height of weir = P, 11.25 feet; length of weir crest = L, 15.969 feet; width of channel = b, 15.970 feet; width of broad crest, 8.980 feet.]

1	27	0.3136	0.3116	0.312	11.563	0.040	0.174	0.312	0.469	2.691
2	20	.1596	.1576	.159	11.410	.014	.064	.159	.163	2.570
3	32	.4196	.4176	.419	11.670	.058	.271	.419	.679	2.504
4	20	3.0666	3.0506	3.058	14.309	.986	5.386	3.073	14.105	2.619
5	19	2.3306	2.3116	2.319	13.569	.686	3.547	2.326	9.307	2.624
6	17	2.8656	2.8486	1.856	13.107	.512	2.537	1.860	6.712	2.646
7	31	1.5166	1.5106	1.513	12.763	.386	1.864	1.515	4.928	2.642
8	28	1.2556	1.2506	1.252	12.503	.297	1.404	1.254	3.718	2.649
9	31	1.0396	1.0356	1.038	12.289	.228	1.059	1.039	2.803	2.646
10	29	.8996	.8916	.897	12.148	.186	.850	.897	2.254	2.652
11	26	.7326	.7306	.732	11.983	.140	.627	.732	1.676	2.676
12	32	.5046	.5006	.502	11.753	.083	.356	.502	.971	2.727



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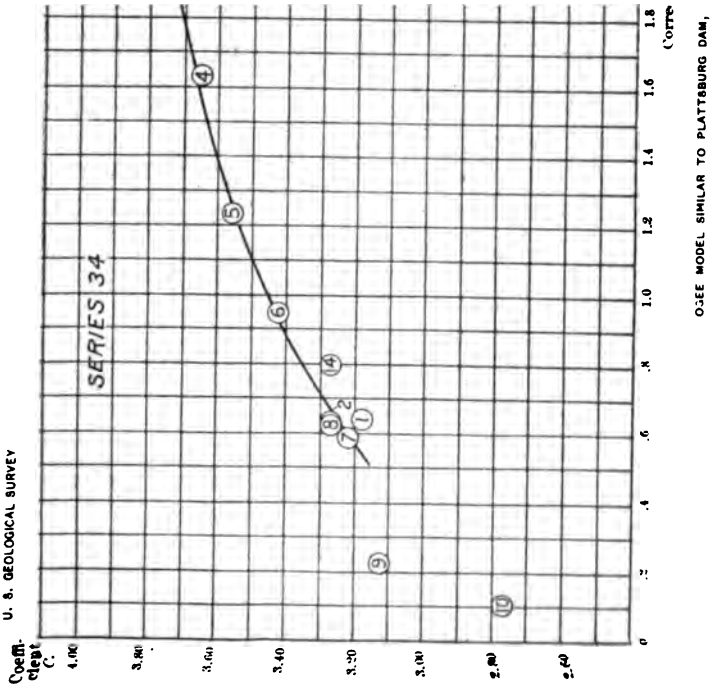

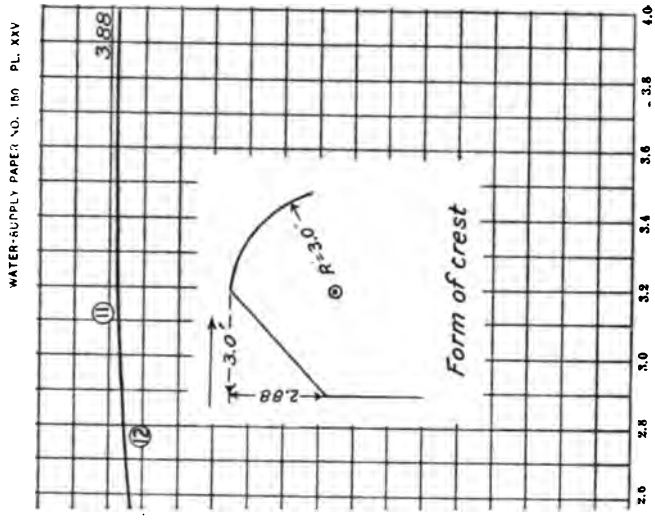

'H OF CREST, 15.989 FEET.

OF FLOW OVER MODEL DAMS,
RY, 1903.

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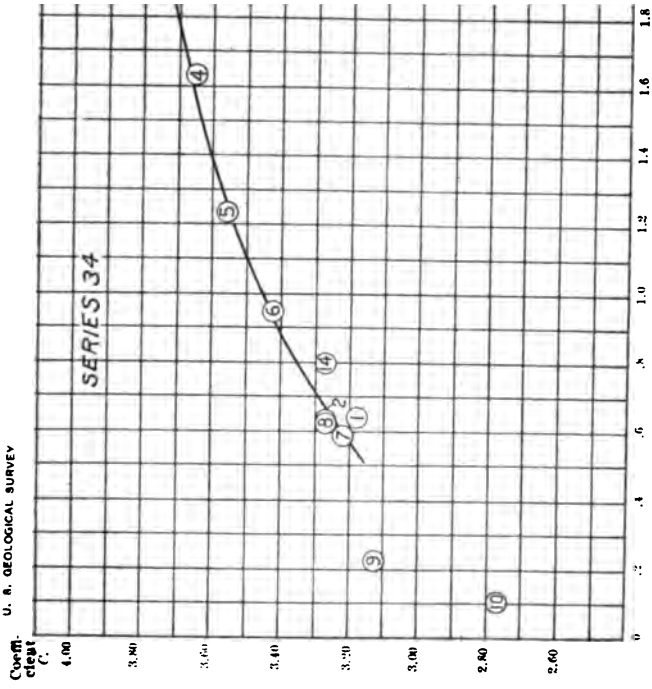


O:EE MODEL SIMILAR TO PLATTSBURG DAM,

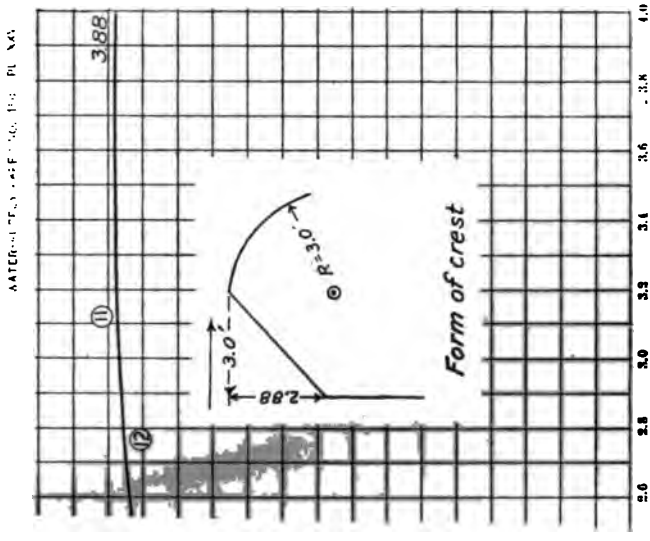
EXPERIMENTS OF UNITED STATES GEOLOG
CORNELL UNIVERSIT

United States Geological Survey experiments at Cornell hydraulic laboratory on model of Merrimac River dam, at Lawrence, Mass.

[Height of weir=P, 6.65 feet; length of weir crest=L, 9.999 feet; width of channel=b, 15.97 feet.]

No.	Measured head on experimental weir, in feet.				A= area of section per foot of crest.	v= mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q=discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
	Number of observations.	Maximum.	Minimum.	Mean= D.			$H^{\frac{3}{2}}$	H		
1	2	3	4	5	6	7	8	9	10	11
1a	.....	.....	.....	4.001	10.651	2.618	8.288	4.094	27.893	3.365
2a	.....	.....	.....	3.930	10.580	2.563	8.054	4.018	27.120	3.367
3a	.....	.....	.....	3.630	10.280	2.309	7.029	3.670	23.740	3.377
21	.....	.....	.....	3.630	10.280	2.319	7.029	3.670	23.738	3.377
10	.....	.....	.....	3.166	9.816	1.939	5.769	3.216	19.039	3.300
11	.....	.....	.....	2.815	9.465	1.654	4.837	2.860	15.660	3.237
22	.....	.....	.....	2.510	9.160	1.424	4.067	2.548	13.049	3.208
23	.....	.....	.....	2.223	8.873	1.200	3.361	2.244	10.652	3.169
12	.....	.....	.....	2.130	8.780	1.127	3.150	2.149	9.898	3.142
1	.....	.....	.....	2.041	8.691	1.066	2.933	2.049	9.265	3.158
24	.....	.....	.....	1.850	8.500	.932	2.542	1.868	7.929	3.113
2	.....	.....	.....	1.746	8.396	.860	2.327	1.756	7.227	3.105
3	.....	.....	.....	1.645	8.295	.802	2.302	1.743	6.651	2.889
13	.....	.....	.....	1.496	8.146	.691	1.832	1.497	5.631	3.074
4	.....	.....	.....	1.322	7.972	.600	1.528	1.327	4.791	3.135
25	.....	.....	.....	1.268	7.918	.556	1.434	1.272	4.410	3.075
5	.....	.....	.....	1.089	7.739	.462	1.141	1.092	3.581	3.138
6	.....	.....	.....	.764	7.414	.284	.669	.765	2.108	3.151
7	.....	.....	.....	.584	7.234	.195	.447	.585	1.412	3.158
9	.....	.....	.....	.583	7.233	.192	.446	.584	1.389	3.114
19	.....	.....	.....	.198	6.848	.039	.088	.198	0.270	3.067

In the accompanying tables (pp. 98–106), columns 2, 3, and 4 show, respectively, the number of observations of head and the maximum and minimum readings in each experimental period. In column 5 is given the mean head on the experimental weir deduced from the tape observations above described. Column 6 shows the area of cross section of the channel of approach per foot of crest. For suppressed weirs this quantity equals the sum of the height of weir plus the measured depth on crest. For weirs with one end contraction the quantity A is obtained by dividing the total area of the water section, where D is measured, by the net length of the weir crest corrected for the end contraction. For those series where the depth on the experimental weir was increased by contracting the weir to about one-half of the channel width and introducing one end contraction, the net length of crest has been determined by the method of Francis, by deducting one tenth the head from the measured length of crest. The discharge per foot of crest of the experimental weir given in column 10 has been deduced from the discharge over the standard weir,



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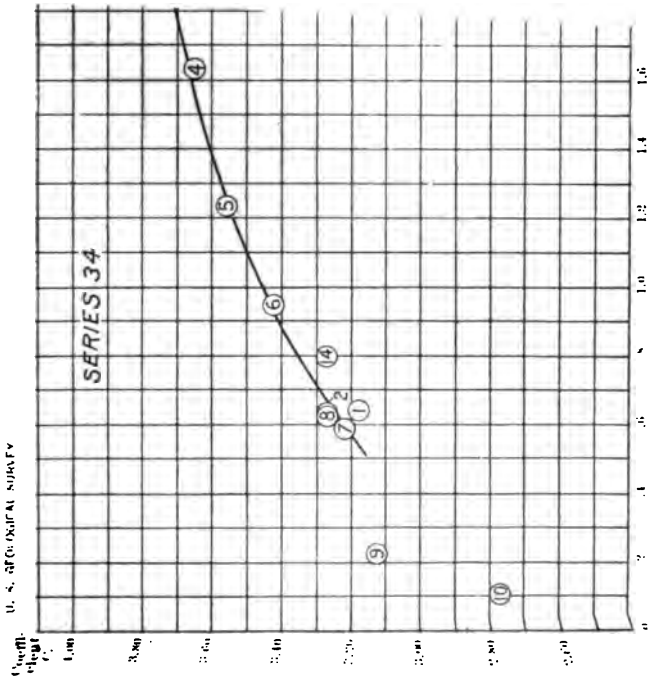


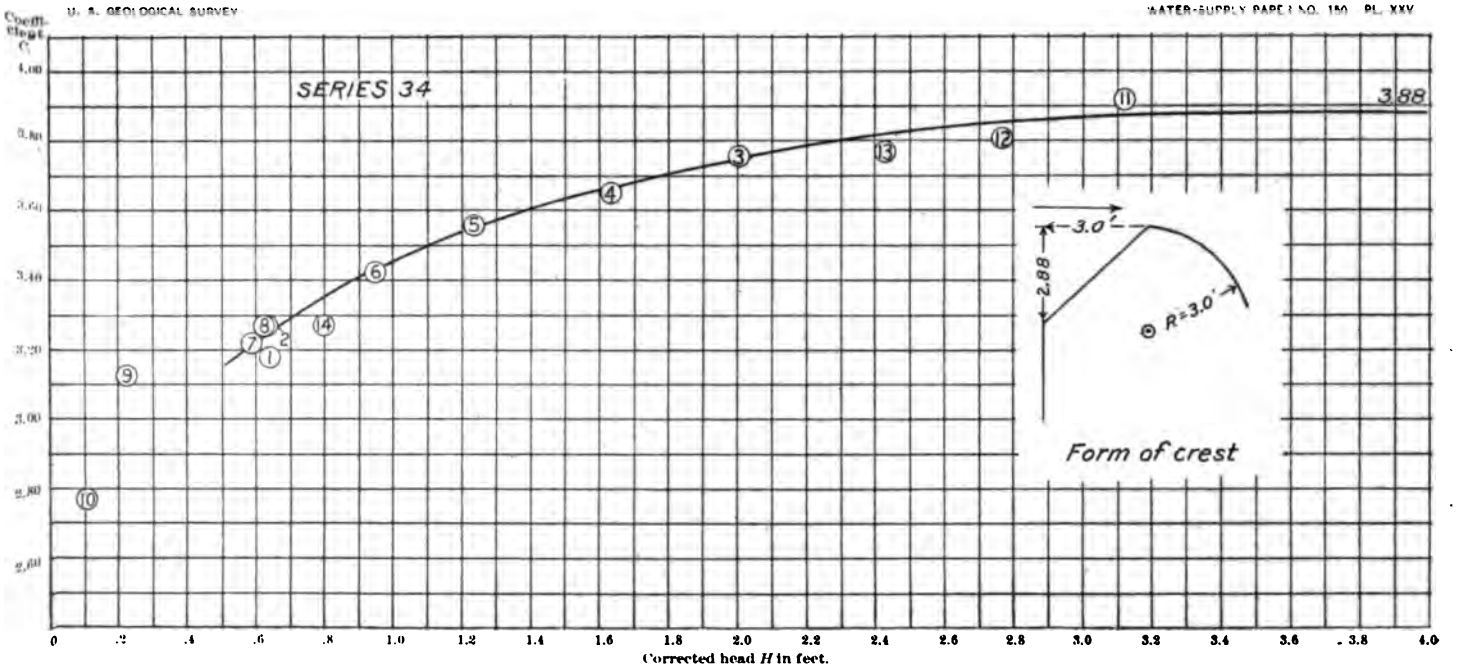
EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS,
CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.

United States Geological Survey experiments at Cornell hydraulic laboratory on model of Merrimac River dam, at Lawrence, Mass.

[Height of weir=P, 6.65 feet; length of weir crest=L, 9.999 feet; width of channel=b, 15.97 feet.]

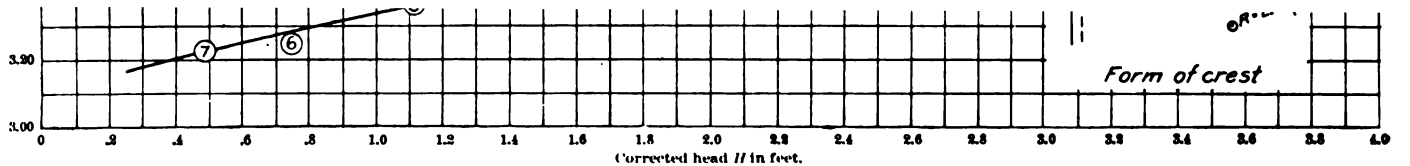
No.	Measured head on experimental weir, in feet.				A= area of section per foot of crest.	v= mean velocity of approach, in feet per second.	Head corrected for velocity of approach, in feet.		Q=discharge per foot of crest, in cubic feet per second.	Discharge coefficient C_1.
	Number of observations.	Maximum.	Minimum.	Mean= D.			$H^{\frac{3}{2}}$	H		
1	2	3	4	5	6	7	8	9	10	11
1c	.....	.....	.....	4.001	10.651	2.618	8.288	4.094	27.893	3.365
2c	.....	.....	.....	3.930	10.580	2.563	8.054	4.018	27.120	3.367
3c	.....	.....	.....	3.630	10.280	2.309	7.029	3.670	23.740	3.377
21	.....	.....	.....	3.630	10.280	2.319	7.029	3.670	23.738	3.377
10	.....	.....	.....	2.166	9.816	1.939	5.769	3.216	19.039	3.300
11	.....	.....	.....	2.815	9.465	1.654	4.837	2.800	15.600	3.237
22	.....	.....	.....	2.510	9.160	1.474	4.067	2.508	13.049	3.208
23	.....	.....	.....	2.223	8.873	1.300	3.361	2.244	10.652	3.169
[illegible]	.....	.....	.....	.584	7.254	.199	.449	.584	1.412	[illegible]
9	.....	.....	.....	.583	7.253	.192	.446	.584	1.389	3.114
19	.....	.....	.....	.198	6.848	.039	.088	.198	0.270	3.067

In the accompanying tables (pp. 98–106), columns 2, 3, and 4 show, respectively, the number of observations of head and the maximum and minimum readings in each experimental period. In column 5 is given the mean head on the experimental weir deduced from the tape observations above described. Column 6 shows the area of cross section of the channel of approach per foot of crest. For suppressed weirs this quantity equals the sum of the height of weir plus the measured depth on crest. For weirs with one end contraction the quantity A is obtained by dividing the total area of the water section, where D is measured, by the net length of the weir crest corrected for the end contraction. For those series where the depth on the experimental weir was increased by contracting the weir to about one-half of the channel width and introducing one end contraction, the net length of crest has been determined by the method of Francis, by deducting one tenth the head from the measured length of crest. The discharge per foot of crest of the experimental weir given in column 10 has been deduced from the discharge over the standard weir.

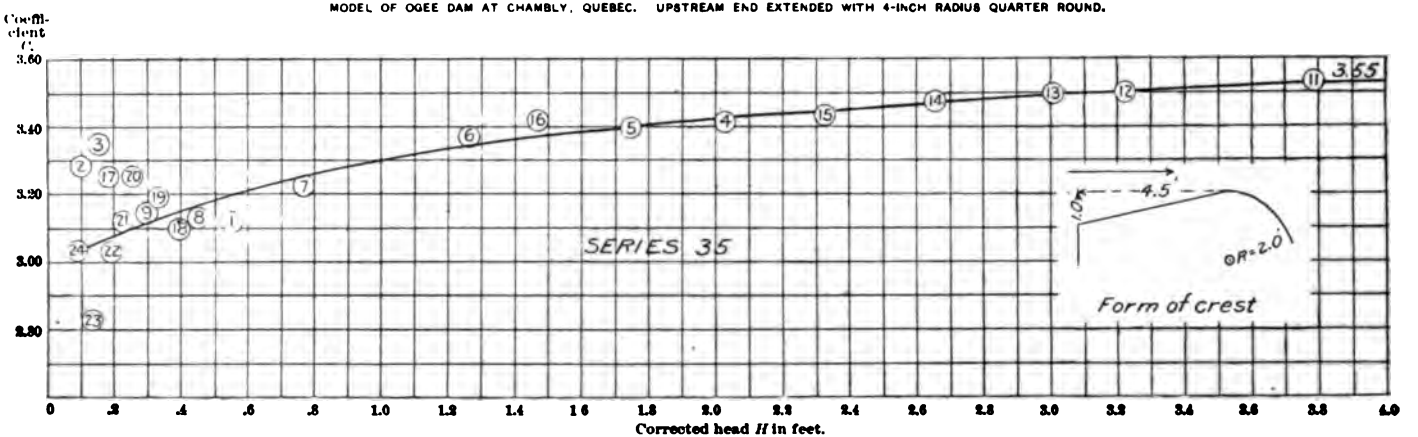


OGEE MODEL SIMILAR TO PLATTSBURG DAM, WITH BACK SLOPE MODIFIED. LENGTH OF CREST, 15.969 FEET.

EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.

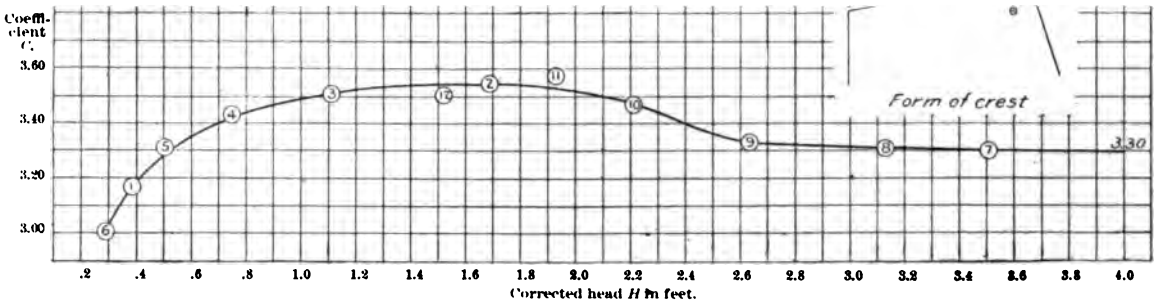


MODEL OF OGEE DAM AT CHAMBLY, QUEBEC. UPSTREAM END EXTENDED WITH 4-INCH RADIUS QUARTER ROUND.

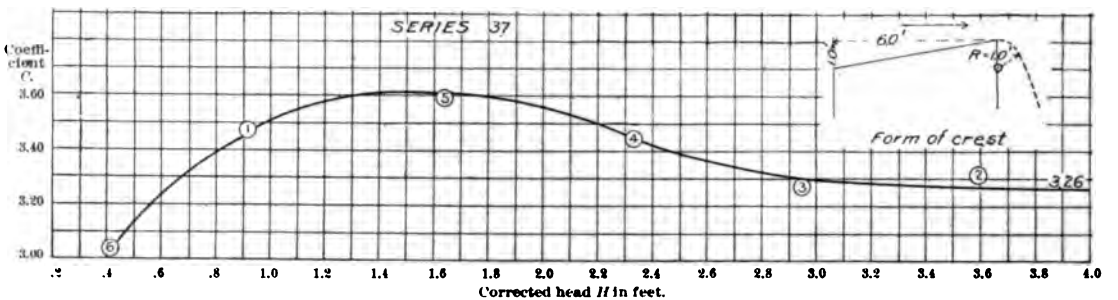


MODEL OF OGEE DAM AT CHAMBLY, QUEBEC. LENGTH OF CREST, 15.000 FEET.

EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.

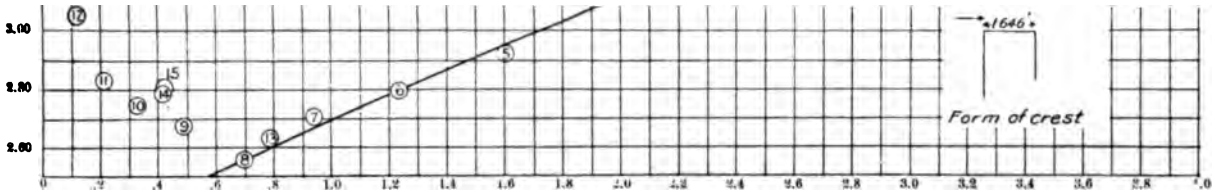


MODEL OF OGEE DAM AT DOLGEVILLE, N. Y. LENGTH OF CREST, 15.969 FEET.

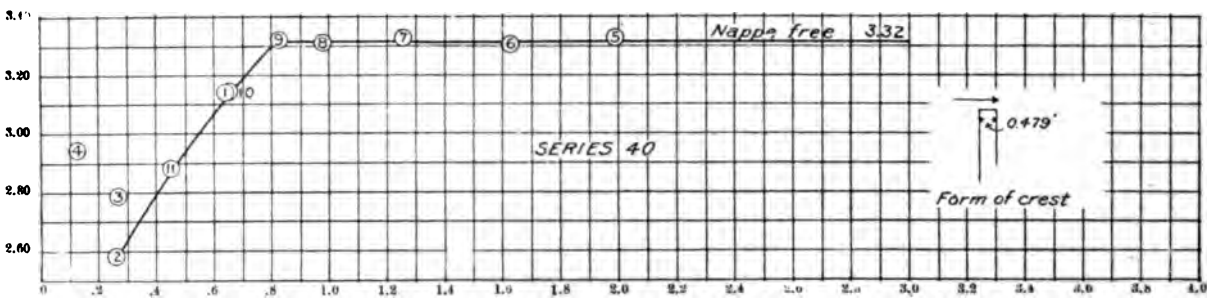


MODEL OF OGEE DAM AT DOLGEVILLE, N. Y. PART OF APRON CARRIED AWAY IN SECOND EXPERIMENT. LENGTH OF CREST, 15.969 FEET.

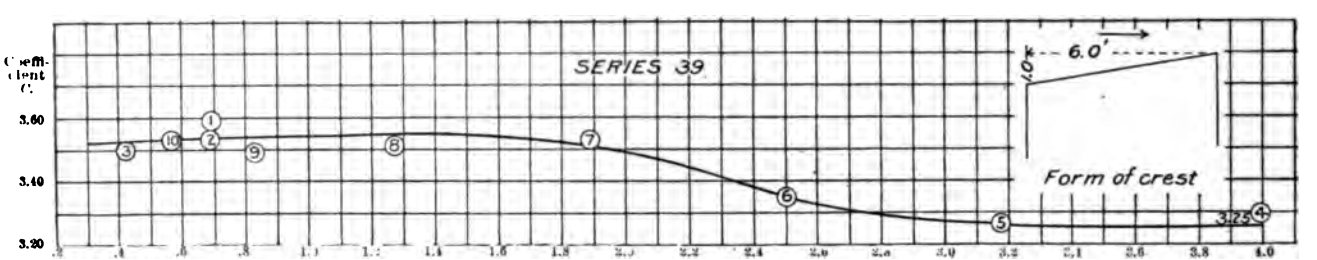
EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.



BROAD-CREST WEIR. WIDTH, 1.646 FEET; LENGTH, 15.969 FEET. NAPPE PARTLY AERATED.

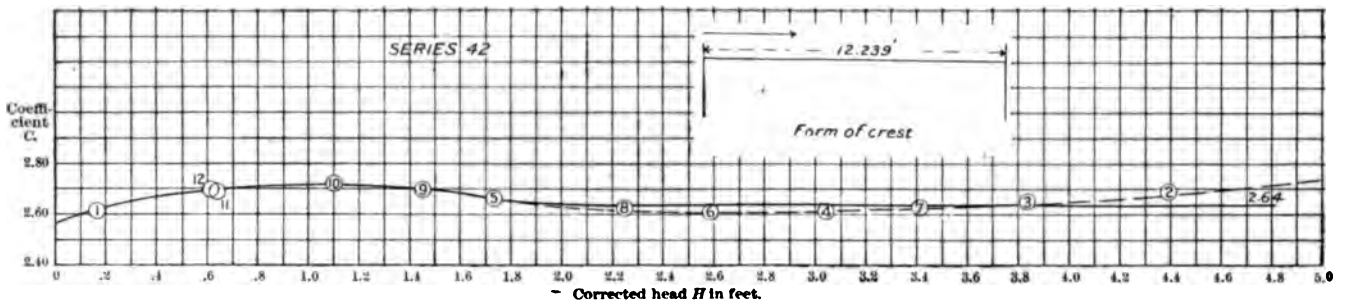


BROAD-CREST WEIR. WIDTH, 0.479 FOOT; LENGTH, 15.969 FEET. NAPPE AERATED.

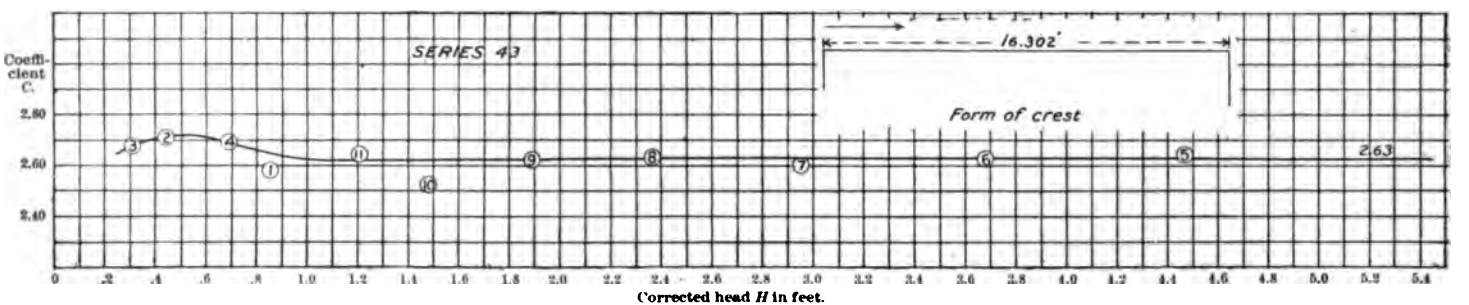


MODEL OF DOLGEVILLE DAM WITH APRON REMOVED, LEAVING TRAPEZOID. LENGTH OF CREST, 15.969 FEET. NAPPE AERATED.

EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.

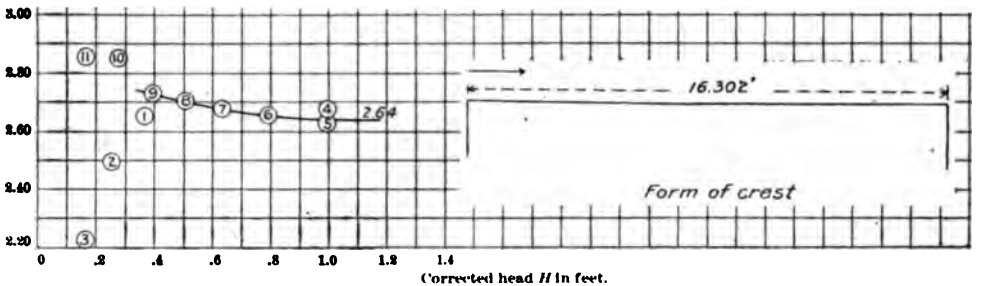


BROAD-CREST WEIR. WIDTH, 12.239 FEET; LENGTH, 15.969 FEET. NAPPE PARTLY AERATED.

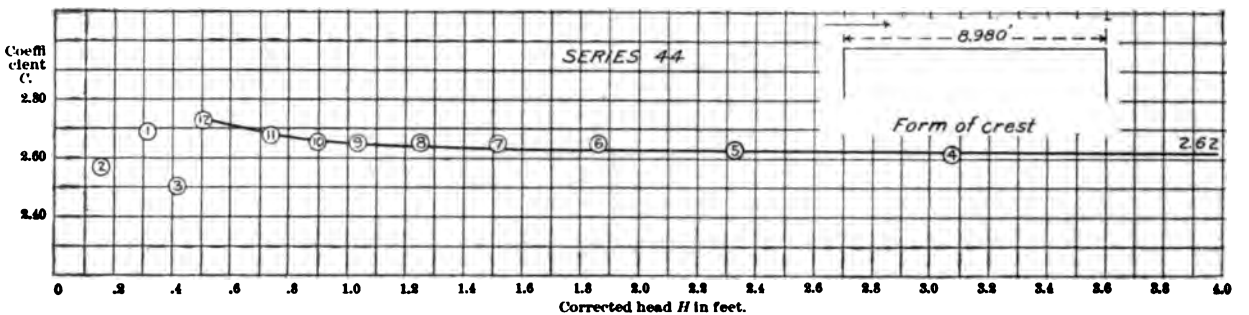


BROAD-CREST WEIR. WIDTH, 16.302 FEET; LENGTH, 15.969 FEET. EDGES OF TRANSVERSE BOARDS NOT FLUSH; NAPPE PARTLY AERATED.

EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.

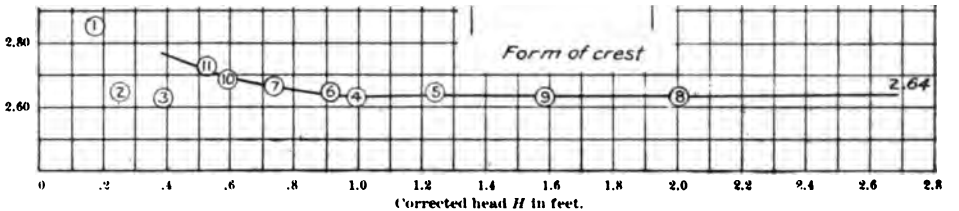


BROAD-CREST WEIR. WIDTH, 16.302 FEET; LENGTH, 15.969 FEET. SMOOTH CREST SURFACE; NAPPE PARTLY AERATED.

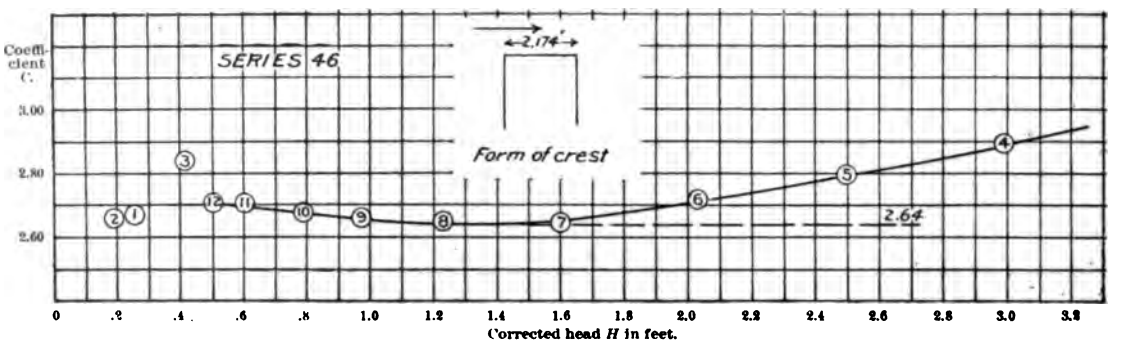


BROAD-CREST WEIR. WIDTH, 8.980 FEET; LENGTH, 15.969 FEET. NAPPE PARTLY AERATED.

EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.

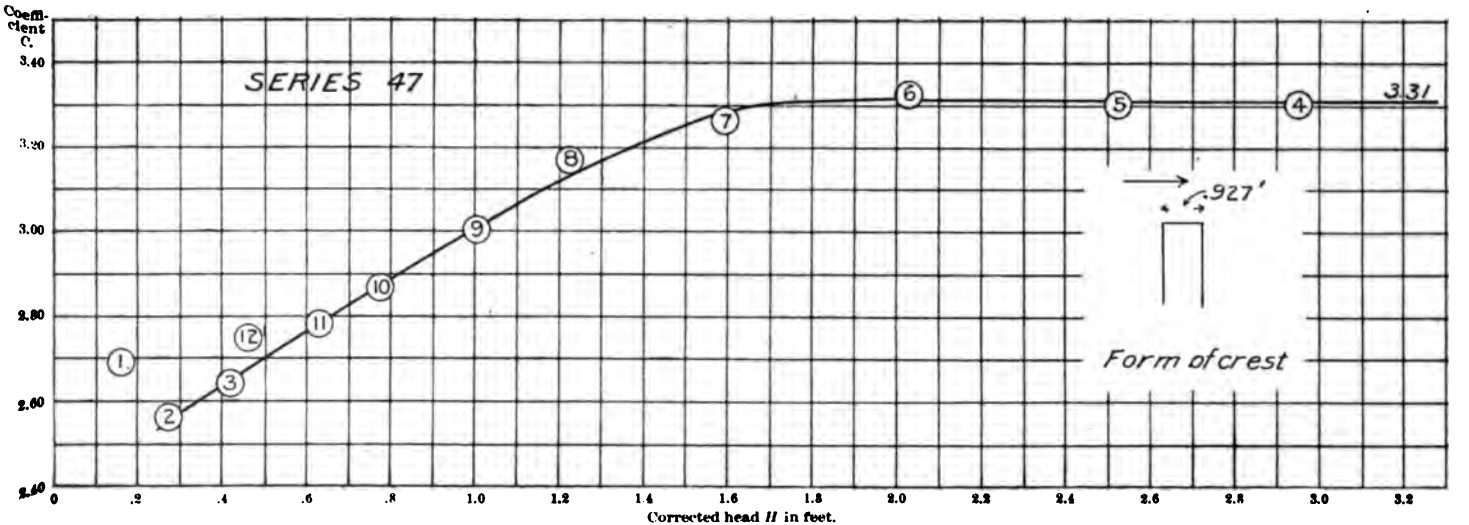


BROAD-CREST WEIR. WIDTH, 5.875 FEET; LENGTH, 15.969 FEET. NAPPE PARTLY AERATED.



BROAD-CREST WEIR. WIDTH, 2.174 FEET; LENGTH, 15.969 FEET. NAPPE PARTLY AERATED.

EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.



BROAD-CREST WEIR. WIDTH, 0.927 FOOT; LENGTH, 15.969 FEET. NAPPE PARTLY AERATED.

EXPERIMENTS OF UNITED STATES GEOLOGICAL SURVEY ON VOLUME OF FLOW OVER MODEL DAMS, CORNELL UNIVERSITY HYDRAULIC LABORATORY. 1903.

›tained, as described above, by dividing the total discharge by the :t length of the experimental weir. The mean velocity of approach given in column 7, has been obtained by the formula

$$v=\frac{Q}{A}.$$

The correction for velocity of approach has been carefully computed y the Francis formula

$$H^{\frac{3}{2}}=(D+h)^{\frac{3}{2}}-h^{\frac{3}{2}},$$

·here

$$h=\frac{v^2}{2g}.$$

The resulting values of $H^{\frac{3}{2}}$ are given in column 8. The correspond- ıg values of H, given in column 9, have been obtained by interpola- ıon from a table of three-halves powers. The discharge coefficient C_1 ı ven in column 11 has been obtained by the formula

$$C_1=\frac{Q}{H^{\frac{3}{2}}}.$$

This coefficient represents the discharge per linear foot of crest, if he head is 1 foot, with no velocity of approach, it being the coefficient n a weir formula of the same form as that used by J. B. Francis for thin-edged weir.

Pls. XXIII to XXXII show the coefficient diagrams deduced from hese experiments.

:XPERIMENTS ON MODEL OF DAM OF THE ESSEX COMPANY, MERRIMAC RIVER, AT LAWRENCE, MASS.[a]

A series of experiments covering five different depths on crest was ıade by James B. Francis at lower locks, Lowell, Mass., November, 852. The model had a crest length of 9.999 feet, with end contractions ıppressed. Height of water was measured by hook gage in a cham- ›er at one side of the channel, 6 feet upstream from crest, so arranged s to give substantially the height of the still-water surface above the rest without correction for velocity of approach. The discharge was 'olumetrically determined as in Francis's thin-edged weir experiments.

The experiments of Francis covered depths on crest ranging from ›.5872 foot to 1.6338 feet. From these experiments he deduced the 'ormula for discharge,

$$Q=3.01208LH^{1.53}.$$

[a] Francis, J. B., Lowell Hydraulic Experiments, pp. 136–137.

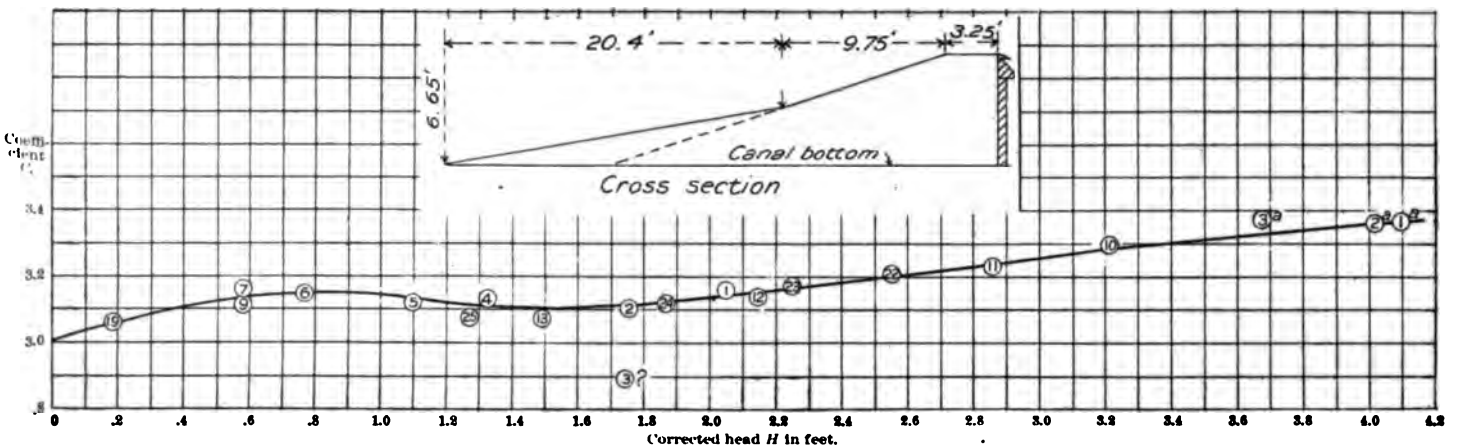
If the discharge were expressed in terms of the usual formula, $Q = C_1 L H^{\frac{3}{2}}$, with a varying coefficient C_1, we should have a continuously increasing coefficient.

A series of experiments on a similar model dam, 6.65 feet high, with crest length of 15.932 feet, was made at Cornell University hydraulic laboratory in 1903. The model there used differed from that shown by Francis only in the substitution of a flatter upstream slope near the bottom of the canal, as shown in Pl. XXXIII. The end contractions were suppressed and the depth on crest was measured with steel tape and plumb bob suspended over center of channel at points 14.67 feet and 29.82 feet, respectively, upstream from crest of experimental weir. Discharge was previously measured over the standard weir, calibrated by Bazin's and Fteley and Stearns's formulas, located at head of experimental canal.

The experiments covered a range of heads varying from 0.198 foot to 4.94 feet. In the majority of the experiments the head was observed at both points. The upper point of measuring depth was at the upstream end of the inclined approach. The lower point was over the incline, where the area of the section of approach was smaller and the velocity larger than in the deeper channel above. The experiments have been reduced with reference to the heads measured 29.82 feet upstream from crest. By comparison of the depths simultaneously observed at the two points correction factors have been deduced for the reduction of the remaining experiments, in which the head was observed at the downstream point of observation only.

The observed head has been corrected for velocity of approach by the formula of Francis. The resulting mean coefficient curve, based on 19 valid observations, shows a larger coefficient of discharge in the formula $Q = C_1 L H^{\frac{3}{2}}$ than does that of Francis.

For a head of 1 foot the formula of Francis for the Merrimac dam gives a discharge of 90.3 per cent of that for a thin-edged weir. The Cornell experiments show 94.5 per cent of the discharge over a thin-edged weir under the same head.



EXPERIMENTS ON MODEL SIMILAR TO MERRIMAC RIVER DAM AT LAWRENCE, MASS., MADE FOR UNITED STATES GEOLOGICAL SURVEY AT CORNELL UNIVERSITY HYDRAULIC LABORATORY, 1903.

scharge per foot of crest, Francis formula for Merrimac dam, compared with Cornell experiments on similar cross section.

epth on rest, H.	Q per foot of crest, in cubic feet per second, Francis.	Coefficient C_1 in formula $Q=C_1LH^{\frac{3}{2}}$.		Depth on crest, H.	Q per foot of crest, in cubic feet per second, Francis.	Coefficient C_1 in formula $Q=C_1LH^{\frac{3}{2}}$.	
		Francis's formula.	Cornell experiments.			Francis's formula.	Cornell experiments.
0.15	0.1653	2.845	3.05	0.85	2.3490	2.997	.....
.20	.2567	2.871	3.06	.90	2.5636	3.002	3.15
.25	.3611	2.889	3.07	.95	2.7846	3.007	3.15
.30	.4774	2.905	3.08	1.00	3.0121	3.012	3.15
.35	.6043	2.913	3.09	1.15	3.7500	3.041	3.13
.40	.7431	2.937	3.11	1.25	4.2378	3.033	3.12
.45	.8877	2.940	3.12	1.50	5.6012	3.048	3.10
.50	1.0430	2.940	3.13	1.75	.....	.....	3.12
.55	1.206	2.956	3.135	2.00	8.6975	3.075	3.14
.60	1.379	2.966	3.14	2.50	.....	.....	3.20
.65	1.5581	2.973	3.14	3.00	16.1750	3.113	3.26
.70	1.7452	2.980	3.14	3.50	.....	.....	3.31
.75	1.9395	2.986	3.14	4.00	25.1200	3.140	3.36
.80	2.1408	2.992	3.15				

Aside from Blackwell's experiments the Francis formula for the Merrimac dam was until recently the only one available for a large dam of irregular section, and for want of more appropriate data it has been used for the calculation of discharge over many forms of weirs of irregular section, and in spite of Francis's explicit caution, it has been applied where the heads differed widely from those used in the original experiments.

Considering the limited experiments on which it is based, Francis's Merrimac dam formula gives good agreement with the much more extended experiments on a similar section made at Cornell hydraulic laboratory.

FLOW OVER WEIRS WITH BROAD CRESTS.

THEORETICAL FORMULA OF UNWIN AND FRIZELL.[a]

Consider a weir of such breadth that the nappe becomes of sensibly uniform depth in the portion BC, fig. 8, the upstream corner of the weir being rounded to prevent vertical contraction and the surface slightly inclined downstream so that it becomes parallel with the surface of the nappe BC.

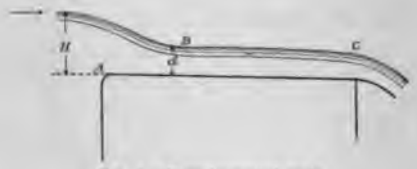


FIG. 8.—Broad-crested weir.

The fall causing the velocity V in the section BC is $H-d$. It follows that if v is the mean velocity in BC

$$v=\sqrt{2g(H-d)} \qquad Q=Ldv=Ld\sqrt{2g(H-d)}$$

In this equation Q is 0 when $d=0$ or $d=H$. There must, therefore, be an intermediate value of d for which Q will be a maximum. Differentiating we find for the condition of a maximum,

$$\frac{dQ}{dd}=0=L\sqrt{2g}\left[\sqrt{H-d}-\frac{1}{2}\frac{d}{\sqrt{H-d}}\right]$$

Giving $H-d=\frac{d}{2}$ and $d=\frac{2}{3}H$, or, for maximum discharge, one-third the head would be expended in producing the velocity of flow. With this value of d the expression for discharge becomes

$$\left.\begin{aligned} &Q=\frac{2}{3}\frac{LH}{\sqrt{3}}\sqrt{2gH}=0.38490LH\sqrt{2gH} \\ \text{or if}\quad &\sqrt{2g}=8.02, \\ &Q=3.087LH^{\frac{3}{2}} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (58)$$

In this formula frictional resistance has been neglected. The discharge given is the maximum for the conditions, and would result only if the stream discharges itself in accordance with the "principle of least energy."

Blackwell's experiments, given elsewhere, show a considerably larger coefficient for weirs 3 feet broad, slightly inclined downward, than for those with horizontal crests.

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[a] Given by W. C. Unwin, in article 1 on Hydrodynamics in Ency. Brit. Independently derived by J. P. Frizell. See his Water Power, pp. 198–200.

; $d=KH$, then from the formula first given

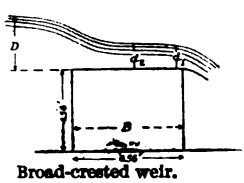
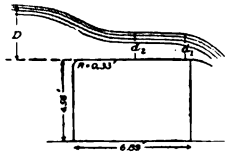
$$Q=LKH\sqrt{2gH(1-K)}$$
$$=K\sqrt{2g(1-K)}LH^{\frac{3}{2}}$$

$$C_1=8.02K\sqrt{1-K} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (59)$$

e theoretical coefficient C_1 can be computed from this equation if s been determined experimentally.

om profiles taken in connection with United States Deep Water- experiments at Cornell University hydraulic laboratory in 1899 ollowing values of D and d for broad-crested weirs have been l and the ratio d D computed. D was taken 4 feet upstream the upper face of the weir, and does not include velocity of oach correction; values of d_1 and d_2 were taken at the lower-crest nd center of crest, respectively. The value of d_2 at center of has been used in the computations.

Values of D and d for broad-crested weirs.

		D	d_1	d_2	$K=\frac{d_2}{D}$
 Broad-crested weir.	1	0.90	0.35	0.52	0.58
	2	1.15	.45	.68	.59
	3	1.80	.75	1.14	.63
	4	2.60	1.20	1.75	.67
	5	3.55	1.72	2.52	.71
	6	5.15	2.20	3.15	.61
 Broad-crested weir.	1	1.00	.35	.50	.50
	2	1.32	.53	.70	.50
	3	1.98	.75	.98	.50
	4	2.85	1.08	1.70	.60
	5	3.90	1.50	2.50	.64
	6	4.65	2.10	3.10	.61

r low heads a sudden drop begins near the upstream crest corner terminates at a distance 1.5 to 2 D below the upstream corner. n this point to within a distance about equal to D from the down- m crest corner the surface is nearly parallel with the crest. e width of crest is not greater than 2.5 to 3 D the nappe passes the broad crest in a continuous surface curve, becoming more y convex as the ratio D B increases.

r low heads Cornell experiment 13, crest 6.56 feet wide, with ded upstream corner, complies very well with the theory of dis-

charge in accordance of the principle of least energy. The coefficient computed as above is

$$C_1 = 8.02 \times 0.585\sqrt{1-0.585}$$
$$= 8.02 \times 0.585 \times 0.6442$$
$$= 3.02$$

The experimental coefficient with head corrected for velocity of approach is 2.82.

The following additional data may be cited:

Trautwine[a] quotes data of Elwood Morris, C. E., for Clegg's dam, Cape Fear River, North Carolina. Horizontal crest 8.42 feet wide, vertical faces. $H=1.25$ feet. d (throughout central portion of crest) $=0.50$ foot. $d/H=0.40$.

Thos. T. Johnston[b] gives data of elaborate profiles of the nappe for Desplaines River dam, Illinois. Horizontal planed stone coping, vertical downstream face; upstream face batter, 1/2:1. $H=0.587$ foot. $d=0.315$ to 0.307 foot in central, nearly level portion at distances 1.5 to 4 feet from upstream edge of crest. Johnston and Cooley deduce the coefficient $C=1.69$ for this case.

BLACKWELL'S EXPERIMENTS ON DISCHARGE OF WATER OVER BROAD-CRESTED WEIRS.

Experiments made by Thomas E. Blackwell,[c] M. Inst. C. E., are of interest as being probably the first recorded for weirs with broad crests. The discharge was volumetrically measured, and the conditions were generally favorable to accuracy. The experiments were made on a side pond of the Kennet and Avon Canal, 106,200 square feet surface area, closed by a lock at each end, the water being admitted from time to time as required, the relation between area of reservoir and volume of discharge being such that there was no sensible variation in water level during an experiment.

The weir was constructed in a dock to which the water had access through an irregularly shaped channel 40 feet in width, cut off from the main pond by a submerged masonry wall 9 feet wide, situated 25 feet upstream from the weir, having its top 18 inches to 20 inches below water surface.

The water level in the pond being constant when outflow took place, the weir, which had a crest adjustable in a vertical plane, was set with its crest level at the depth below water surface desired for an experiment, by means of adjusting screws at the ends of the weir; the water

[a] Engineers' Pocket Book.

[b] Johnston, T. T., and Cooley, E. L., New experimental data for flow over a broad-crest dam: Jour. Western Soc. Engrs., vol. 1, Jan., 1896, pp. 30–51.

[c] Original paper before Institution of Civil Engineers of London, reprinted in the Journal of the Franklin Institute, Philadelphia, March and April, 1852.

was then allowed to waste through the weir until a uniform regimen of flow was established.

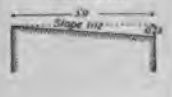
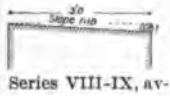
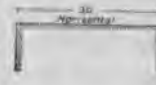
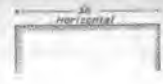
A gaging tank having a floor of brick laid in cement, with plank sides, and 449.39 cubic feet capacity, was erected at the foot of the weir. At a given signal the lid of this tank was raised, the time noted, and the rate of filling of the tank recorded by several observers. Such leakage from the tank as occurred was separately measured and allowed for. There was no correction for velocity of approach or for end contractions.

The wind was so slight as to be negligible, except during one series when there was a brisk wind blowing downstream. The experimenter states that parallel experiments on a quiet day indicated an increase of about 5 per cent in discharge due to this wind.

The crest of the thin-edged weir consisted of an iron plate barely one-sixteenth inch thick. A square-top plank 2 inches thick was attached to the weir, and an apron of deal boards, roughly planed so as to form an uninterrupted continuation downstream, constituted the wide-crested weir used in the experiments.

The coefficient C_1 from Blackwell's experiments has been worked out and is given in the following table. The measured depths taken in inches have also been reduced to feet.

Blackwell's experiments on broad-crested weirs, Kennet and Avon Canal, England, 1850.

Weir.	Measured head, in inches.	Head, in feet.	Q per foot, in cub. ft. per sec.	M	$C_1=M\sqrt{2g}$
II. Thin plate, 10 feet long.	1	0.083	0.104	0.539	4.32
	2	.167	.292	.585	4.29
	3	.25	.429	.428	3.43
	4	.333	.675	.437	3.50
	5	.417	.935	.433	3.47
	8	.667	1.691	.387	3.10
	9	.750	1.842	.353	2.83
VII. L=3 feet. 	1	.083	.060	.311	2.49
	2	.167	.194	.355	2.85
	3	.250	.360	.359	2.88
	4	.333	.468	.303	2.43
	6	.500	1.005	.354	2.84
	7	.583	1.254	.351	2.82
	9	.750	1.729	.332	2.66
Series VII, average	.....	.....	.....	.....	2.71
VIII. L=3 feet.	1	.083	.070	.363	2.91
	2	.167	.199	.364	2.92
	3	.250	.359	.358	2.87
	4	.333	.443	.287	2.30
	5	.417	.743	.344	2.76
	7	.583	1.222	.342	2.74
	8	.667	1.426	.327	2.62
	9	.750	1.709	.328	2.63
IX. L=10 feet. 	1 to 1½	.073	.060	.311	2.49
	2	.167	.181	.330	2.65
	4	.333	.530	.343	2.75
	6	.500	1.028	.362	2.90
	8	.667	1.476	.338	2.71
Series VIII-IX, average	.....	.....	.....	.....	2.71
X. L=3 feet. 	1	0.083	0.058	0.301	2.41
	2	.167	.175	.321	2.57
	3	.250	.295	.294	2.36
	4	.333	.431	.279	2.24
	5	.417	.689	.319	2.56
	6	.500	.947	.334	2.68
	7	.583	1.162	.325	2.61
	8	.667	1.369	.313	2.51
	9	.750	1.642	.317	2.54
XI. L=6 feet.	1to1½	.093	.071	.....	.....
	3	.250	.329	.328	2.63
	4	.333	.511	.331	2.65
	6	.500	.963	.....	.....
	7	.583	1.191	.331	2.65
	9	.750	1.670	.....	.....
	10	.883	1.895	.310	2.49
	12	1.0	2.495	.311	2.49
XII. L=10 feet. 	1	.083	.049	.254	2.04
	2	.167	.174	.319	2.56
	5	.417	.745	.345	2.77
	6	.500	.972	.342	2.74
	8	.667	1.362	.312	2.50
	9	.750	1.688	.324	2.60
	10	.833	1.847	.303	2.43
Series X, XI, XII, average	.....	.....	.....	.....	52.03 2.48

EAST INDIAN ENGINEERS' FORMULA FOR BROAD-CRESTED WEIRS.[a]

This formula is

$$Q=\frac{2}{3}M'LH\sqrt{2gH},\text{ or if }\sqrt{2g}=8.02,\ Q=5.35\,M'LH^{\frac{3}{2}}=C_1LH^{\frac{3}{2}} \quad (60)$$

Where M'=coefficient for thin-edged weir[b]$=0.654-0.01H$,

$$M'=M-\frac{0.025\,M\,(B+1)}{H+1} \quad . \quad . \quad . \quad . \quad . \quad (61)$$

[a] Mullins, Gen. Joseph, Irrigation Manual, Madras, 1890.
[b] See table giving values of M and equivalent values of C, p. 22.

Experimental data not given. This formula gives values of M' or C_1 decreasing as breadth of crest B increases, and for low heads increasing to a maximum for a head of about 1 foot, then slowly decreasing.

The formula reduces to

$$C_1 = C'\left(\frac{H+1-0.025\,(B+1)}{H+1}\right) = RC \quad . \quad . \quad . \quad (62)$$

For $B=0$

$$C_1 = C'\frac{H+0.975}{H+1} = RC$$

which differs by the ratio R from the equivalent value of C' for a thin-edged weir.

Values of coefficient C_1 of discharge over a broad-crested weir and of R, the ratio of the former to C' the coefficient of discharge over a thin-edged weir, by Mullins's formula.

H feet. \ B	1 foot.		2 feet.		3 feet.		4 feet.	
	R	C_1	R	C_1	R	C_1	R	C_1
1	0.975	3.359	0.962	3.316	0.95	3.319	0.938	3.230
2	.983	3.335	.975	3.307	.967	3.279	.958	3.251
3	.988	3.296	.981	3.275	.975	3.255	.969	3.234
4	.990	3.253	.985	3.237	.98	3.220	.975	3.204
5	.992	3.204	.988	3.191	.983	3.177	.979	3.164
6	.993	3.155	.989	3.144	.986	3.132	.982	3.121
7	.994	3.104	.991	3.095	.988	3.085	.984	3.075
8	.994	3.054	.992	3.045	.989	3.037	.986	3.028
9	.995	3.003	.992	2.995	.99	2.988	.988	3.042
10	.995	2.950	.993	2.944	.991	2.937	.989	2.930

H feet. \ B	5 feet.		6 feet.		7 feet.		8 feet.	
	R	C_1	R	C_1	R	C_1	R	C_1
1	0.925	3.182	0.912	3.144	0.9	3.100	0.888	3.057
2	.95	3.22	.942	3.194	.933	3.166	.925	3.138
3	.962	3.213	.956	3.192	.95	3.171	.944	3.150
4	.97	3.193	.965	3.171	.96	3.154	.955	3.138
5	.975	3.149	.971	3.137	.967	3.123	.962	3.110
6	.978	3.11	.975	3.098	.971	3.080	.968	3.076
7	.981	3.06	.978	3.057	.975	3.046	.972	3.036
8	.983	3.017	.980	3.012	.977	2.999	.975	2.994
9	.985	2.97	.982	2.966	.98	3.019	.978	2.950
10	.986	2.92	.984	2.916	.982	2.910	.979	2.093

The values of C_1 given in the above table have been deduced from the corresponding values of C' for a thin-edged weir by Mullins's formula. The ratio R may, if desired, be applied approximately to correct values of C derived from other standard weir formulas.

FTELEY AND STEARNS EXPERIMENTS ON BROAD-CRESTED WEIRS.[a]

The formula of Fteley and Stearns is based on five series of experiments made in the Sudbury River conduit, Boston, 1877, on weirs 2, 3, 4, 6, and 10 inches wide, respectively. Suppressed weirs 5 feet long were used, the depths being as follows:

Fteley and Stearns experiments.

Width of crest, in inches.	Number of experiments.	Range of depth observed on broad crests, in feet.	
		From—	To—
2	7	0.1158	0.2926
3	21	.1307	.4619
4	25	.1318	.6484
6	22	.1320	.8075
10	17	.1352	.8941

The results are given by the authors in the form of a table of corrections to be added algebraically to the measured head for the broad-crested weir to obtain the head on a thin-edged weir that would give the same discharge.

Fteley and Stearns's correction c may be found approximately from the formula

$$c=0.2016\sqrt{[(0.807\,B-H)^2+0.2146\,B^2]}-0.1876\,B \quad . \quad . \quad (63)$$

or if $k=0.2016$, $m=0.1876$, $n=0.2146$, $O=0.807$, then

$$Q=CL\,[H-mB+k\sqrt{(OB-H)^2+nB^2}]^{\frac{3}{2}} \quad . \quad . \quad . \quad (64)$$

If the head on a broad-crested weir is H, the discharge will be

$$Q=CL(H+c)^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (65)$$

C being the coefficient of discharge for thin-edged weirs.

If C_1 is the coefficient for the broad weir, then we may also write

$$Q=C_1LH^{\frac{3}{2}}.$$

Hence

$$\frac{C_1}{C}=\left(\frac{H+c}{H}\right)^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (66)$$

From formula (66) have been calculated Fteley and Stearns's coefficients for weirs with nappe adhering to crest for use in the formula

$$Q=CLH^{\frac{3}{2}},$$

[a] Fteley and Stearns, Experiments on the flow of water, etc.: Trans. Am. Soc. C. E., vol. 12, pp. 86-96.

correction for velocity of approach being made by adding $1.5\frac{v^2}{2g}$ to the measured head to obtain H.[a]

Values of the ratio $\frac{C_1}{C}$ of the coefficient of discharge for a broad-crested weir, by Fteley and Stearns's experiments, to that for a thin-edged weir.

H	Width of crest, in inches.					
	3	4	6	8	10	12
0.0	.....	.....	.....	.....	.....	.....
.1	0.7466	0.74798	0.7562	0.7589	0.7576	0.7576
.2	.8234	.7878	.7740	.7679	.7644	.7624
.3	.9172	.8524	.8003	.7809	.7727	.7685
.4	.9963	.9201	.8353	.8003	.7850	.7768
.5	.....	.9806	.8781	.8255	.8003	.7865
.6	.....	1.0080	.9230	.8567	.8199	.7989
.7	.....	.....	.9391	.8911	.8424	.8150
.8	.....	.....	.9997	.9245	.8695	.8339
.9	.....	.....	1.0317	.9553	.8983	.8552
1.0	.....	.....	.....	.9835	.9406	.8824
1.1	.....	.....	.....	1.0090	.9508	.9027
1.2	.....	.....	.....	1.0317	.9732	.9252
1.3	.....	.....	.....	1.0499	.9948	.9465
1.4	.....	.....	.....	.....	1.0148	.9657
1.5	.....	.....	.....	.....	1.0317	.9850

BAZIN'S FORMULA AND EXPERIMENTS ON BROAD-CRESTED WEIRS.

These included series of about 20 periods each for depths not exceeding 1.4 feet on weirs of 0.164, 0.328, 0.656, 1.315, 2.62, and 6.56 feet breadth of crest. The coefficient C_1 in the formula $Q = C_1 L H^{\frac{3}{2}}$, deduced from a recomputation of the experiments on weirs 2.46 feet high, using the Francis velocity of approach correction, is given on Pl. IV.

Other experiments were made for the four narrower weirs with heights 1.148 and 1.64 feet, to determine the comparative velocity of approach effect.

Bazin shows that if the nappe is free from the downstream face of the weir it may assume two forms: (1) It may adhere to the horizontal crest surface; (2) it may become detached at the upstream edge in such a manner as to flow over the crest without touching the downstream edge. In the second case the influence of the flat crest evidently disappears and the discharge is like that over a thin-edged weir. The nappe usually assumes this form when the depth D exceeds twice the breadth of crest B, but it may occur whenever the depth exceeds $\frac{3}{2}B$. Between these limits the nappe is in a state of instability; it tends to detach itself from the crest, and may do so under the

[a] Fteley and Stearns's formula for a thin-edged weir has been used to calculate Q in deriving the coefficients, the experiments having been made under conditions similar to those under which the formula was derived.

nfluence of any external disturbance, as, for example, the entrance of air or the passage of a floating object over the weir.

When the nappe adheres to the crest, the coefficient C_1 depends chiefly on the ratio D/B and may be represented by the formula

$$C_1 = C\,(0.70 + 0.185\ D/B) \quad . \quad . \quad . \quad . \quad . \quad (67)$$

n which C is the coefficient for a thin-edged weir.

When $D/B = 1.50$ to 2, $C_1/C = 0.98$ to 1.07 if the nappe adheres to crest, or $C_1/C = 1.00$ if nappe is detached, and for $D/B > 2$, $C_1/C = 1.00$. Between the limits $D = 1.5B$ and $D = 2B$ the value which the coefficient C_1 will assume in a particular case is uncertain. Bazin considers that his formula gives accurate results for adhering nappes with breadth of crests up to 2 or 3 feet. For a crest 6.56 feet wide and $D = 1.476$ feet he finds the result by formula (67) 93.4 per cent of that given directly by the experiment.

Values of the ratio C_1/C, for a broad-crested weir, with adhering nappe, by Bazin's formula.[a]

D/B	$C_1/C = 0.700 + 0.185\ D/B$.									
	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.700	0.7018	0.7037	0.7056	0.7074	0.7092	0.7111	0.7130	0.7148	0.7166
.1	.7185	.7204	.7222	.7240	.7259	.7278	.7296	.7314	.7333	.7352
.2	.7370	.7388	.7407	.7426	.7444	.7462	.7481	.7500	.7518	.7536
.3	.7555	.7574	.7592	.7610	.7629	.7648	.7666	.7684	.7703	.7722
.4	.7740	.7758	.7777	.7796	.7814	.7832	.7851	.7870	.7888	.7906
.5	.7925	.7944	.7962	.7980	.7999	.8018	.8036	.8054	.8073	.8092
.6	.8110	.8128	.8147	.8166	.8184	.8202	.8221	.8240	.8258	.8276
.7	.8295	.8314	.8332	.8350	.8369	.8388	.8406	.8424	.8443	.8462
.8	.8480	.8498	.8517	.8536	.8554	.8572	.8591	.8610	.8628	.8646
.9	.8665	.8684	.8702	.8720	.8739	.8758	.8776	.8794	.8813	.8832
1.0	.8850	.8868	.8887	.8906	.8924	.8942	.8961	.8980	.8998	.9016
1.1	.9035	.9054	.9072	.9090	.9109	.9128	.9146	.9164	.9183	.9202
1.2	.9220	.9238	.9257	.9276	.9294	.9312	.9331	.9350	.9368	.9386
1.3	.9405	.9424	.9442	.9460	.9479	.9498	.9516	.9534	.9553	.9572
1.4	.9590	.9608	.9627	.9646	.9664	.9682	.9701	.9719	.9738	.9756
1.5	.9775	.9794	.9812	.9830	.9849	.9868	.9886	.9904	.9923	.9942

[a] If there is velocity of approach, the value of D/B, not H/B, should be used as an argument. The ratio C_1/C may be applied in a formula which includes the velocity of approach correction, either in the head H or in the coefficient.

Bazin's formula gives ratios which continually increase as H increases, B remaining constant, and which continually decrease as B increases, H remaining constant. It gives, however, a constant ratio for all widths or heads where the ratio H/B is unchanged.

Compared with their respective standard weir formulas, Mullins's formula gives for a broad-crested weir a continuously decreasing ratio of discharge as B increases from zero, H remaining constant, and a continuously increasing discharge as H increases from zero, B remaining constant; Fteley and Stearns's experiments give a discharge ratio which is less than unity, but which varies in an irregular manner, depending on the head and breadth of weir.

On referring to Pl. IV, in which the Bazin coefficients are given in a orm comparable with the experiments of the United States Geological Survey, it will be noticed that, except for the lowest heads, the coefficient curves are simple linear functions of the head. The rate of ncrease of the coefficients as the head increases grows rapidly less s the breadth of the weir increases, indicating that for a very broad veir the coefficient would be sensibly constant throughout the range of stability of the nappe.

For the narrower weirs the coefficients tend to increase rapidly almost from the start toward the value for a thin-edged weir or detached nappe. For the weirs 2.62 and 6.56 feet breadth of crest the total variation in the coefficient for the range of heads covered by the experiments is comparatively small. The average coefficients are as follows:

Average Bazin coefficients, broad-crested weirs.

Bazin series No.	Crest width, in feet.	Range of head, in feet.		Average constant coefficient, C_1.
		From—	To—	
113	1.312	Lowest.	0.60	2.64
114	2.624	0.35	.85	2.59
			1.32	2.62
115	6.56	.55	Highest.	[a] 2.58

[a] Coefficient increases slowly throughout.

The average coefficients show a fair agreement with the constant coefficient for broad-crested weirs with stable nappe deduced from the experiments of the United States Geological Survey (page 120).

EXPERIMENTS OF THE UNITED STATES GEOLOGICAL SURVEY ON BROAD-CRESTED WEIRS.

The method of conducting these experiments and the detailed results are given on pages 95–107. The coefficient curves are presented on Pls. XXVIII to XXXII. It may be remarked here that the models were larger and the range of breadth of crest and depth of flow experimented upon was greater than in the earlier experiments described. In general, the laws of behavior of the nappe pointed out by Fteley and Stearns and Bazin were confirmed.

The following table presents a résumé of the results:

Résumé of United States Geological Survey experiments on broad-crested weirs.

Series.	Breadth of crest, in feet.	Nappe unstable for heads less than values below, in feet.	Nappe detached from crest at head, in feet.	Coefficient C_1 varies between the limits—				Coefficient constant.	
				Head, in feet.		Coefficient.			
				From—	To—	From—	To—	Above head, in feet.	C_1
40	0.479	0.3	0.8	0.3	0.8	2.64	3.32	0.8	3.32
47	.927	.3	1.8	.3	1.8	2.57	3.31	1.8	3.31
41	1.646	.7	2.8	.7	2.8	2.56	3.32	2.8	3.32
46	3.174	.5	.....	.5	1.3	2.70	2.64	1.3	Increases
45	5.875	.5	.....	.5	.9	2.72	2.64	.9	2.64
44	8.980	.5	.....	.5	2.0	2.73	2.62	2.0	2.62
42	12.289	.....	.....	.2	2.0	2.62 2.73	2.64	2.0	[a] 2.64
43	16.302	.....	.....	.3	1.1	2.68	2.72 2.63	1.1	[b] 2.63
43a	16.302	.4	.....	.4	1.0	2.72	2.64	1.0	2.64
Average	.....	.....	.....	.....	.....	.....	.....	.....	2.634

[a] Coefficient shows tendency to increase slowly with head.
[b] Edges of planed and matched boards not flush. Crest smoothed in series 43a.

The deductions that follow have been based on a consideration of earlier experiments as well as those here given for the first time.

1. For depths below 0.3 to 0.5 foot the nappe is very unstable, owing probably to magnified effect of crest friction and to the varying aeration or adhesion of the nappe to the downstream weir face.

2. For heads from 0.5 foot to 1 or 2 feet for very broad weirs, or from 0.5 foot to the point of detachment for narrower weirs, the coefficient is somewhat variable and changes in an uncertain manner. For the broader weirs, the range of variation of C_1 between the depths indicated is narrow, from 2.73 to 2.62.

3. When the nappe becomes detached the coefficient remains nearly identical with that for a thin-edged weir. For the narrower weirs the coefficient increases rapidly within the range of tendency to detachment indicated by Bazin, i. e., for heads between D and $2D$.

4. On the broader weirs for depths exceeding 1 to 2 feet up to the limit of the experiments (about 5 feet), the experiments indicate a sensibly constant coefficient for all depths. Where there is any tendency to variation within the range indicated there is a gradual increase in C_1.

For weirs of 5 to 16 feet breadth the experiments show no conspicuous tendency for the coefficient C_1 to change with variation in either H or B, the range of value of C_1 being from 2.62 to 2.64.

The line of detachment of the nappe for a weir of 5 feet breadth would be 7.5 to 10 feet head or perhaps more, and a higher head for

roader crests. If this depth were ever reached it may be surmised hat the coefficient C_1 would increase to about 3.33 at the point of etachment. It would also appear, as is in fact indicated in Bazin's ormula, that the coefficient should very slowly increase with H and ecrease as B increases, independent of the tendency to detachment f the nappe, and owing to the decreased relative effect of crest friction and contraction.

The United States Geological Survey experiments indicate that this ffect is of relatively little significance for large heads and broad weirs, nd hence a constant coefficient covering a wide range may be safely dopted.

The average coefficient, 2.64, which we have tentatively chosen for veirs exceeding 3 feet in breadth under heads exceeding 2 feet, may pparently be applied for considerably lower heads for weirs of 5 feet or more crest breadth with but small error.

TABLE OF DISCHARGE OVER BROAD-CRESTED WEIRS WITH STABLE NAPPE.

A table has been calculated, using $C_1=2.64$ and covering heads varying by 0.1 foot increment from zero to 10 feet (p. 177). It is considered applicable for weirs of 3 feet or more crest breadth when H/B lies between the general limits 0.25 to 1.5. The coefficient 2.64 gives a discharge 79.2 per cent of that for a thin-edged weir by the Francis formula. The relative discharge obtained by other formulas and experimenters is shown in the following table:

Comparison of broad-crested weir formulas and experiments giving percentage of discharge over a thin-edged weir.[a]

Formula or experiments.	1 foot width.			2.62 feet width.			6.56 feet width.			
	H/B=0.5	1.0	1.5	0.5	1.0	1.5	0.25	0.5	1.0	1.5
	H=0.5	1.0	1.5	1.31	2.62	3.93	1.64	3.28	6.56	9.84
Mullins[b]	96.7	97.5	98.0	.....	.....	.....	93.2	95.5	97.5	98.2
Fteley and Stearns	78.6	88.2	98.5	.....	.....	.....	.....	.....	.....	.....
Bazin formula	79.2	88.5	97.8	79.2	88.5	97.8	74.6	79.2	88.5	97.8
U. S. Deep Waterways experiments	.....	.....	.....	82.8	93.3	114.1	72.0	71.1	72.3	73.2
U. S. Geological Survey experiments	81.0	90.3	97.5	[c]79.5	[c]81.3	[c]86.7	79.2	[d]79.2	[d]79.2	[d]79.2

[a] No velocity of approach.
[b] East Indian engineers' formula, given in Mullins's Irrigation Manual, Madras Presidency.
[c] Weir 2.17 feet broad.
[d] Weir 5.88 feet broad.

Considering the low heads used, it may be noted that before Bazin's experiments only those of Blackwell included a weir breadth sufficient to eliminate the early tendency to detachment and permit the existence of the stable period for which a constant coefficient applies.

Blackwell's experiments on weirs 3 feet broad indicate a maximum coefficient C_1 of 2.65 to 2.77 for a head of about 0.5 foot, decreasing as the head increased.

The experiments of the United States Deep Waterways Board on models with 2.62 and 6.56 foot crest width are shown on Pl. XV. For the narrower weir the coefficient increased uniformly with the head. The nappe did not leave the crest, although the experiments were continued to the limit $H/B=2$, at which stage the coefficient exceeded that for a thin-edged weir. For the broader weir the coefficients are much less variable and the curves indicate that the coefficients approach a constant as the breadth of crest is increased.

It will be noted that considerable care must be exercised in determining the condition of the nappe for broad-crested weirs of inconsiderable width, while for those of greater breadth the wind may exert considerable influence on the nappe on the broad crest under lower heads. The constant coefficient 2.64 has been deduced from experiments on weirs with smooth, planed crests and sharp upstream crest angles. The effect of crest roughness on weir discharge is discussed on page 133.

EFFECT OF ROUNDING UPSTREAM CREST EDGE.

Experiments by Fteley and Stearns[a] indicate that the effect of rounding the upstream crest corner is to virtually lower the weir, by allowing the water to pass over with less vertical contraction. To determine the discharge over a thin-edged weir, with upstream crest corner rounded to a radius R, add to the measured head the quantity

$$K=0.70R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (68)$$

The above formula was deduced by Fteley and Stearns from experiments on weirs with crest radii of one-fourth, one-half, and 1 inch. For heads not exceeding 0.17, 0.26, and 0.45 foot, respectively, the nappe adhered to the crest, and the formula does not apply.

The correction formula (68) is equivalent to increasing the discharge coefficient in the ratio

$$\left(\frac{H+0.7R}{H}\right)^{\frac{3}{2}}$$

or nearly in the ratio

$$\frac{H+R}{H}.$$

A second series of experiments was made with rounded upstream edges of similar radii applied to a crest 4 inches wide, giving the correction formula for this case,

$$K=0.41R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (69)$$

[a] *Experiments on the flow of water, etc.*: Trans. Am. Soc. C. E., vol. 12, pp. 97-101.

e K' is a correction to be added to the measured head before ;ing the formula for discharge over the broad-crested weir. This ula is applicable for depths of not less than 0.17 and 0.26 foot, ;ctively, on weirs with radii of one-fourth and one-half inch. ;y and Stearns's formulas show the effect to decrease with the lth of crest. It also decreases, when expressed as a percentage, the head. These formulas are probably applicable to weirs with ler, though not to those with greatly larger, radii than those of the rimental weirs.

zin experimented upon two weirs, duplicated in the United States ı Waterways experiments, having crest widths of 2.624 and 6.56 respectively, with an upstream crest radius of 0.328 foot (Pl.

Broad-crested weirs with rounded upstream corner.

Head, in feet.	Coefficient C_1, Bazin's experiments.			
	Crest width, 2.62 feet.		Crest width, 6.56 feet.	
	With angle crest.	With rounded crest.	With angle crest.	With rounded crest.
0.25	2.52	2.85	2.40	2.58
.50	2.59	2.95	2.515	2.76
1.00	2.64	3.00	2.575	2.89
1.50	2.69	3.04	2.635	2.92
	Coefficient C_1, United States Deep Waterways experiments.			
1.50	2.67	2.92	2.39	2.81
2.00	2.75	3.00	2.41	2.81
3.00	2.93	3.17	2.44	2.81
4.00	3.11	3.34	2.47	2.81
5.00	3.30	3.51	2.50	2.81
6.00	Nappe free.	3.00	2.53	2.81

nited States Deep Waterways series 14 and 15, Pl. XV, show the t of rounding the upstream crest corner, radius 0.33 foot, on a el of the Rexford flats, New York, dam. In this case, with a 22 feet broad with 6:1 slope on each face, the effect of rounding mes comparatively slight, the average increase being about 2 ;ent.

nited States Geological Survey experiments, series Nos. XXXV XXXVI, Pl. XXVI, show the effect of the addition of a 4-inch ıs (0.33 foot), quarter-round extension to the upstream face of the el of an ogee-section dam, having 4.5 feet crest width, 4.5:1 slope.

Effect of rounded upstream crest corner on an ogee dam.

Head, in feet.	Chambly model, series 35.	Same, with rounded upstream crest corner.	Difference per cent of Francis's coefficient.
0.50	3.18	3.22	+1.5
1.00	3.30	3.34	+1.2
2.00	3.42	3.51	+2.7
3.00	3.49	3.64	+4.5

EXPERIMENTS ON WEIRS WITH DOWNSTREAM SLOPE, OR APRON, OF VARYING INCLINATION.

Aside from the experiments of Blackwell on weirs with very slight inclination and a few series by other experimenters on weirs of irregular section involving aprons, the data on this subject are limited to those of Bazin's experiments.

Bazin selected a number of weir types, each having a constant top width, height, and upstream inclination and applied to each a number of different downstream slopes.[a]

TRIANGULAR WEIRS WITH VERTICAL UPSTREAM FACE AND SLOPING APRONS.

Such weirs are occasionally used, as where the apron slopes to the stream bed in log slides. A similar form in which the downstream slope terminates at a greater or less distance from the vertical upstream face is not uncommon, and to this form the Bazin experiments may probably be applied, provided the breadth of the sloping apron is considerable. The experiments are of special interest, however, as showing the effect of attaching a sloping apron to the downstream face of a thin-edged weir, and by inference affording an indication of the effect of a similar apron attached to any form of cross section. The results of Bazin's experiments recomputed on the basis of the Francis formula are shown on Pl. V.

Four series of experiments on weirs 2.46 feet high are included. For all these series the coefficient C tends to remain nearly constant for the range of heads covered, 0.2 foot to 1.5 feet, there being a slight increase in C with the lower heads only.

Two series on weirs 1.64 feet high are also given. In series 145, slope of apron 3 : 1, there is a general increase in coefficient with head below 0.9 foot. Series 138, for a weir 1.64 feet high, is duplicated on a weir 2.46 feet high, and the latter series is given preference in the general curve. The lower weirs indicate in both cases slightly higher coefficients, possibly owing to the incomplete elimination of the effect of excessive velocity of approach.

[a] Bazin did not attempt to collate the results extensively. His general résumé has been translated by the writer, and may be found in Rept. U. S. Board of Engineers on Deep Waterways, pt. 2, 1900, pp. 646–658.

The average constant coefficients for the several series are shown in he following table:

Mean coefficients, triangular weirs with varying apron slope.

Series.	Height.	Slope.	Range of head.		Range of C.		Average C.
			From—	To—	From—	To—	
136	2.46	1 : 1	0.3	1.40	3.84	3.88	3.85
137	2.46	2 : 1	.3	1.6	3.48	3.52	3.50
138	1.64	2 : 1	.7	1.5	3.56	3.58	3.57
145	1.64	3 : 1	.9	1.5	3.39	3.41	3.40
141	2.46	5 : 1	.6	1.5	3.08	3.14	3.13
142	2.46	10 : 1	.75	1.5	2.90	2.93	2.91

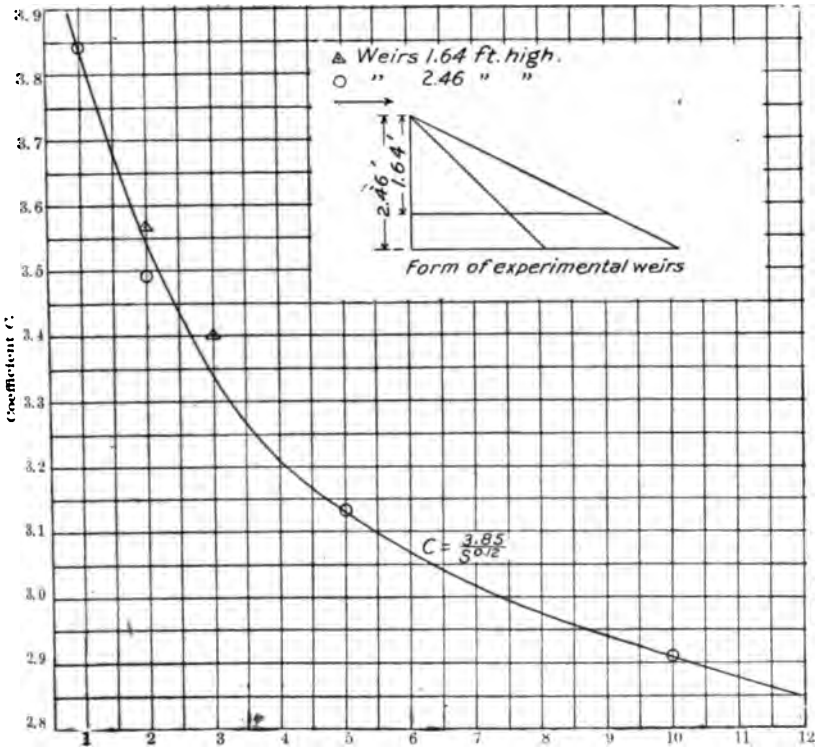


FIG. 9.—Coefficient curve for triangular weirs.

The mean coefficients have also been plotted on fig. 9 and a general curve drawn. This curve becomes approximately a straight line when plotted on logarithmic cross-section paper. Its equation expressed in logarithmic form is

$$C = \frac{3.85}{S^{0.12}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (70)$$

where S is the batter or slope of apron.

If $S=6$, then, solving by logarithms,

$$\log 6=0.7781513$$
$$\log 6^{0.12}=0.0933782$$
$$\log \frac{1}{6^{0.12}}=9.9066218$$
$$\log 3.85=0.5854607$$
$$\log C=0.4920825$$
$$C=3.105$$

Fig. 9 gives C=3.07; the difference is 1 per cent.

The following conclusions deduced from the recomputed data conform in general with those of Bazin:

1. For steep apron slopes where the nappe tends to break free, the apron materially increases the discharge by permitting a partial vacuum to be formed underneath the nappe.

2. For flat apron slopes the conditions approach those for a horizontal crest.

3. For an apron slope of about 3:1, the discharge is nearly the same as for a thin-edged weir.

4. For slopes greater than 3:1 the apron diminishes the discharge the amount of diminution increasing as the slope becomes flatter.

TRIANGULAR WEIRS WITH UPSTREAM BATTER 1:1 AND VARYING SLOPE OF APRON.

Three series of experiments by Bazin are included (Pl. IX), all made from weirs 1.64 feet high. The results are comparable among themselves, but owing to the high velocity of approach their general applicability is less certain.

Series No. 161, downstream slope 1:1, shows a generally decreasing coefficient with an apparent tendency to become constant through a narrow range of heads, from 0.5 to 0.9 foot, with C=about 4.11.

Series No. 163 and 165, with apron slopes of 2:1 and 5:1, give coefficient lines, which may be fairly represented by the constants 3.82 and 3.47, respectively. These coefficients compare with those for vertical weirs with the same apron slopes as follows:

Comparative coefficients.

Batter of apron.	Vertical face. C	Face inclined 1:1. C	Difference, per cent, Francis's coefficient.
1:1	3.85	4.11	+ 7.8
2:1	3.53	3.82	+ 8.7
5:1	3.13	3.47	+10.2

XPERIMENTS ON WEIRS OF TRAPEZOIDAL SECTION WITH UPSTREAM SLOPE OF ½:1, HORIZONTAL CREST, AND VARYING DOWNSTREAM SLOPES.

Five series of Bazin's experiments on weirs 2.46 feet high, with rest width of 0.66 foot, are shown on Pls. VI and VII. The curves ıdicate coefficients increasing with the head, the rate of increase being ıore rapid for the steeper apron slopes. There is a tendency to epression at about 0.4 foot head, representing, possibly, the point at hich the nappe changes from adhering to depressed condition on the ownstream face. The curves are all convex, and apparently approach constant, which was not, however, reached within the limit of experiıents, except, perhaps, for the flattest slope of 5:1. The coefficients ıcrease in value as the steepness of the apron slope increases.

Three series of experiments on weirs similar to those above described, ıut with flat crests 1.317 feet wide, are shown on Pl. VIII. The oefficient curves are of uncertain form for heads below 0.6 foot. For greater heads they may be represented by inclined straight ines. The coefficients increase uniformly with the head, the initial values for 0.6 foot head being nearly the same for the several slopes, the increase being more rapid for the steeper downstream slopes.

It may be seen from the following table that increased width of the flat crest, as compared with that of the preceding weir, causes a decrease in the discharge.

Comparative coefficients at 1-foot head, weirs with flat crests and ½:1 upstream slope.

Slope of apron.	Crest width, in feet.	
	0.66	1.317
1:1	3.52	.....
2:1	3.38	2.985
3:1	3.265	.....
4:1	3.205	2.94
5:1	3.195	.....
6:1	.....	2.93

COMBINATION OF COEFFICIENTS FOR WEIRS WITH COMPOUND SLOPES.

Series 163 for an apron slope 2:1 represents a weir form which would be produced by placing, vertical face to vertical face, a weir with back slope 1:1 and a weir with apron slope 2:1. For the former, Bazin's experiments indicate 10 per cent excess discharge over that for a thin-edged weir, and for the latter (from Pl. V) $C=3.50$, equivalent to 5

per cent excess over a thin-edged weir. If the discharge over the 1:1 upstream slope was similarly increased by the addition of an apron, C would be $3.66 \times 1.05 = 3.84$. Pl. IX indicates $C = 3.82$.

The above method of determining the coefficient for weir of irregular cross section by combining the coefficients for two principal elements of which it is composed, as separate weirs, is restricted in its application and may lead to inconsistencies.

WEIRS WITH VARYING SLOPE OF UPSTREAM FACE.

Experiments were made by Bazin on thin-edged weirs inclined at various angles. Bazin found the ratio of the coefficient of discharge to that for a vertical thin-edged weir to be sensibly constant for all heads within the limits of his experiments, 0.0 to 1.5 feet. Bazin's results were expressed in the form of a modulus by which to multiply the coefficient for a vertical weir to obtain that for an inclined weir. Assuming the Francis coefficient 3.33 to apply to a vertical weir, the coefficients for weirs of various inclinations would be as follows:

Coefficients for inclined weirs, Bazin's experiments.

		Bazin's modulus.	C
Upstream inclination of the weir	1 horizontal to 1 vertical	0.93	3.097
	2 horizontal to 3 vertical	.94	3.130
	1 horizontal to 3 vertical	.96	3.197
Vertical weir		1.00	3.330
Downstream inclination of the weir	1 horizontal to 3 vertical	1.04	3.463
	2 horizontal to 3 vertical	1.07	3.563
	1 horizontal to 1 vertical	1.10	3.663
	2 horizontal to 1 vertical	1.12	3.996
	4 horizontal to 1 vertical	1.09	3.630

On Pl. XVI are shown the results of United States Deep Waterways experiments on weirs 4.9 feet high, having horizontal crests 0.67 foot broad, and with various inclinations of the upstream slope. The experiments cover heads from 1.75 to 5.2 feet, but only 3 or 4 points are given on each coefficient curve. The results indicate in a general way, however, nearly constant coefficients for each inclination of the upstream face. The values of the coefficients are considerably smaller than those obtained by Bazin, whose experiments were on weirs 2.46 feet high with sharp crests.

Pls. X, XI, and XII show the results of experiments of Bazin on weirs of irregular section, with various upstream slopes. Pl. X includes 5 series of experiments on weirs 1.64 feet high, with sharp

ıgles, and 2 : 1 downstream slopes. The coefficient curves lepression period at from 0.3 to 0.7 foot head, beyond which icients may be fairly represented by constants up to 1.5 foot e limit of the experiment). A general curve showing the coefficient in terms of a downstream slope or batter has been This indicates a maximum coefficient of discharge for an ı slope of about 2.6 : 1. Bazin found, for thin-edged weirs, lined downstream slopes, a maximum coefficient for an incli- f 30°, or 1¾ : 1.

.I and XII show coefficient curves for weirs having the same ı slopes as in Pl. X, but 2.46 feet high, and with flat crests t wide. The coefficient curves are convex outward, indicating y may approach constant values at some point beyond the f the experiments. The marked difference in character of efficient curves, as compared with those in the preceding s notable. For weirs with flat crests 0.67 foot wide the ıts for a given head uniformly increase as the slope becomes p to a batter of about 1¾ : 1. They are also greater for all ithin the limit of the experiments than the coefficients for th sharp crest angles. The comparative values are indicated llowing table:

Comparative coefficients, weirs with varying upstream slope.

Upstream slope.	Pl. X, sharp crest, 2:1 downstream slope; average constant coefficient.	Pls. XI and XII, 0.67 feet crest width, 2:1 downstream slope. Head, in feet.		
		0.5	1.0	1.5
	C	C	C	C
Vert.	3.58	2.78	3.26	3.51
⅓ : 1	3.68	2.87	3.34	3.56
½ : 1	3.72	2.92	3.38	3.62
1 : 1	3.83	3.03	3.42	3.65
2 : 1	3.87	3.13	3.43	3.61

be seen that the addition of the flat crest has an effect in this llar to that observed in Pls. VI and VIII, showing the results iments by Bazin on weirs with various downstream slopes.

l States Deep Waterways series No. 7, Pl. XVII, may be d with Bazin's series No. 178, shown on Pl. XI. The former coefficient of 3.55 for a head of 2 feet on a weir 4.895 feet coefficient slowly increasing with the head. The latter gives ent of 3.6 for a head of 1.5 feet, decreasing rapidly as the reases.

United States Geological Survey series No. XXXIX, Pl. XXVIII, and United States Deep Waterways series No. 18, Pl. XVIII, represent weirs with vertical downstream faces and inclined crests. The upstream slope does not, however, extend back to the bottom of the channel of approach, but is cut off abruptly by a vertical upstream face. The average coefficients deduced from these series have been plotted on a general curve on Pl. XVI, the coefficients agreeing closely with those of the United States Deep Waterways experiments on weirs of similar upstream slope, extending to the channel bottom. United States Geological Survey series No. XXX represents the Dolgeville dam, with rounded crest removed, leaving a trapezoid with crest 6 feet broad and 1 foot lower at upstream than at downstream edge. The coefficient is not constant, but apparently approaches a constant value of about 3.25 for heads exceeding 3 feet. United States Deep Waterways series No. 18 represents a model of the spillway of the Indian Lake dam, having a crest 7 feet wide, 1.5 feet lower at upstream than at downstream edge, which gives an average constant coefficient of 3.42.

It is suggested that if the upstream slope of an inclined weir is continued back 6 feet or more and terminates in a vertical upstream face, the discharge coefficient will not differ materially from that for an upstream slope extending to the channel bottom.

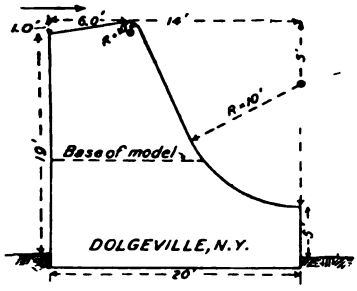
DAMS OF OGEE CROSS SECTION, PLATTSBURG-CHAMBLY TYPE.

The United States Geological Survey experiments on dams of this type are shown on Pls. XXIII to XXVII. Cross sections of the various dams, with lines indicating the comparative size of the models used in the United States Geological Survey experiments, are shown on Pl. XXXIV. Cross sections of other ogee dams used as weirs are shown on Pl. XXXV.

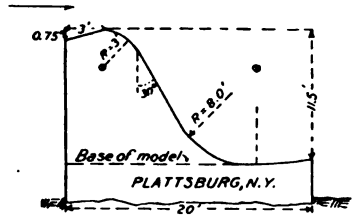
This class includes dams with downstream crest radius sufficiently large to retain the nappe always in contact, yet not so large as to simulate a broad flat crest. We thus exclude the Dolgeville section on the one hand, in which the nappe as observed in the existing dam partially or completely breaks free near the crest for other than very low stages, and on the other hand, the Austin dam, with a crest radius of 20 feet, which appears, from the meager data available, to lie outside this class.

We have arranged the available data in order, advancing with decreased breadth and increased inclination of sloping upstream face.

The coefficients for various depths are as follows:



(A)



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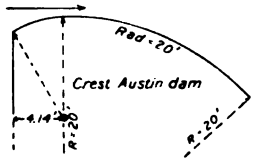

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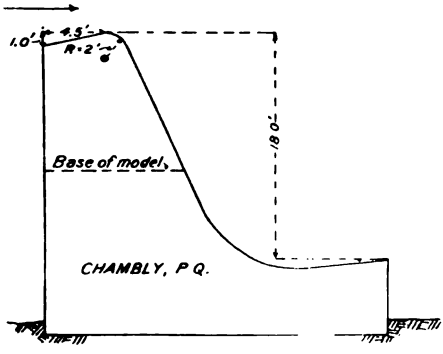
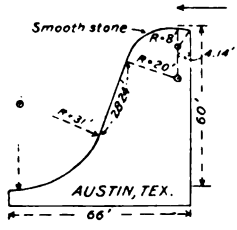
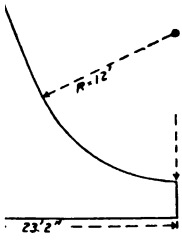


(C)

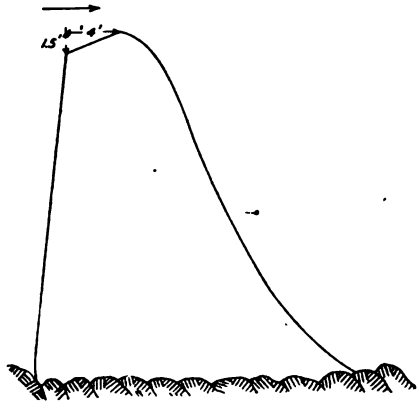


(D)

COMPARATIVE SIZE OF MODELS AND SECTIONS OF OGEE DAMS.

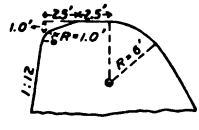


ER RIVER, N.Y.

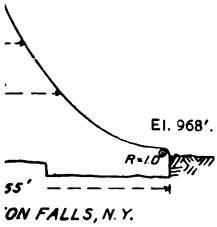


HANNAWA FALLS, N.Y.

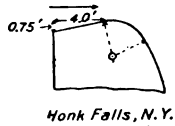
9.0'



Crest, Trenton Falls



ON FALLS, N.Y.

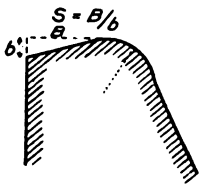


Honk Falls, N.Y.
Crest section

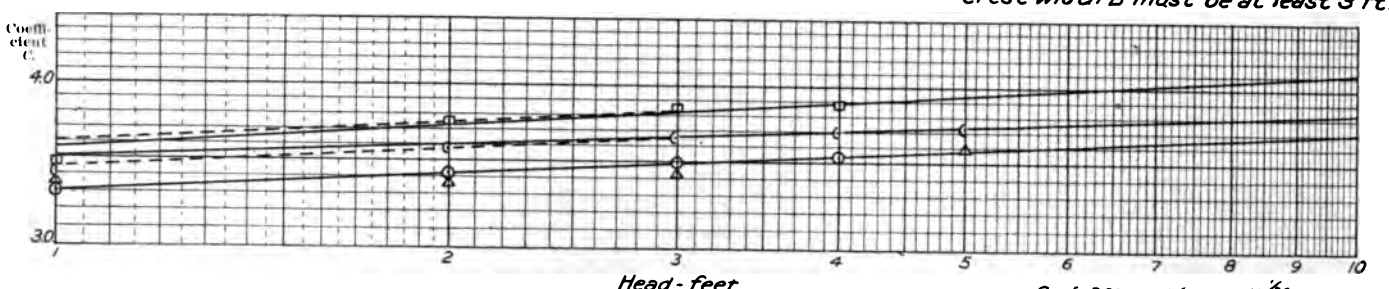
CROSS SECTIONS OF OGEE DAMS.

Experimental data

Series	Symbol		Crest slope	Crest width
U.S.G.S. 30-31	△	Plattsburg (Reg)	4:1	3
" 32-33	◐	" (Spec)	2:1	3
" 34	□	" "	1.04:1	3
" 35	○	Chambly	4.5:1	4.5



Note – Crest radius must be such that nappe adheres to face of dam
Crest width B must be at least 3 ft.



$C = [\,3.62 - .16(S-1)\,]\,H^{1/20}$

Example $S = 2:1$ $H = 4.0$

$C = 3.46 \times 4^{1/20}$

$\text{Log } 4^{1/20} = .03103$ $4^{1/20} = 1.0716$

$C = 3.708$ computed

$C =$ from experiments 3.70

COEFFICIENT DIAGRAM FOR OGEE DAMS.

Comparative coefficients, dams of ogee cross section.

.m	Chambly.	Plattsburg.	Modified Plattsburg.					
•prox. constant coefficient	3.435	3.48	3.48	3.48	3.70	3.70	3.70	.....
eadth of slope, in feet	4.5	3	3	3	3	3	3	3
tter of slope	4½:1	4:1	4:1	4:1	2:1	2:1	2:1	1.04:1
est radius, in feet	2.0	3.0	3.0	.3.0	3.0	3.0	3.0	3.0
:periment	.....	U.S.G.S.	U.S.G.S.	Mean of	U.S.G.S.	U.S.G.S.	Mean of	U.S.G.S.
rles	.....	a 30	b 31	30–31	b 32	a 33	32–33	34
ead 0.5 foot	.....	3.22	.....	.....	3.29	3.22	3.255	.....
1.0 foot	3.30	3.43	3.29	3.36	3.37	3.44	3.405	3.46
2.0 feet	3.42	3.42	3.35	3.385	3.51	3.67	3.59	3.75
3.0 feet	3.49	3.47	3.43	3.45	3.57	3.72	3.645	3.87
4.0 feet	3.53	3.52	3.54	3.53	3.67	3.74	3.705	3.88
5.0 feet	.....	.....	3.62	.....	3.73	.....	.....	.....
6.0 feet	.....	.....	.....	.....	.....	.....	.....	.....

a 15.969 feet crest length, without end contraction.
b 7.979 feet crest length, one end contraction.

It appears that the rounded crest changes the character of the law ' coefficient from a value tending toward a constant for each back ɔpe to a slowly increasing function of the head. Compared with the ›nstant coefficients for weirs with similar upstream slopes extending ıck to canal bottom, and with vertical faces, we find that the conant values deduced for these cases correspond with the values of the ırying coefficients for ogee sections at a medium head of 2 to 4 feet.

By plotting the data for weirs of ogee section on logarithmic cross-ction paper the following convenient approximate formula has been ɜduced, applicable for weirs with 2 or 3 feet crest radius and upream slopes 3 to 4.5 feet broad. S indicates the batter ratio of the ope, $\frac{\text{horizontal run}}{\text{vertical rise}}$.

$$C=[3.62-0.16\,(S-1)]\,H^{\frac{1}{20}} \quad . \quad . \quad . \quad . \quad . \quad (71)$$

f $S=2:1$ $\quad H=4.0 \quad C=3.46\times 4^{\frac{1}{20}}$

$$\log 4^{\frac{1}{20}}=0.030103 \qquad C=3.46\times 1.0716=3.70.$$

The experiments give $C=3.74$.

EXPERIMENTS ON DISCHARGE OVER ACTUAL DAMS.

On Pl. XXXVII are shown the results of a number of experiments made by measuring the discharge over existing dams by means of floats or current meters. Aside from those for the Austin, Tex., dam, the data have been collected by Mr. George T. Nelles.[a]

[a] Discussion of paper by G. W. Rafter on the flow of water over dams: Trans. Am. Soc. C. E., vol. 14, pp. 359–362.

BLACKSTONE RIVER AT ALBION, MASS.

This is a timber dam 217 feet long, with horizontal crest 1 foot wide, vertical downstream face, and upstream slope covered with riprap. Discharge was measured by current meter 500 feet below dam, and the depth was measured by hook gage 20 feet upstream from crest. Coefficients have not been corrected to eliminate velocity of approach. They illustrate the uncertainty of discharge for broad-crested weirs of small width under low heads.

MUSKINGUM RIVER, OHIO.

Discharge was measured by rod floats in a cross section 500 feet above the dams, which are constructed of timber cribs filled with stone. Data by Maj. W. H. Bixby, U. S. Army.

Discharge data for Muskingum River dams.

Number of dam.	Length on crest, in feet.	Mean height, in feet.	Area of discharge section, in square feet.	Discharge, in cubic feet per second.	Mean velocity, in feet per second.	Fall over dam, in feet.	Observed depth on crest, in feet.	Coefficient C.
3	848	12.6	7,765	18,118	2.333	8.00	2.86	4.419
4	535	15.9	8,360	25,559	3.045	6.70	4.66	4.723
7	472	14.2	8,230	21,015	2.553	7.00	4.40	4.812
8	515	16.0	7,330	22,310	3.044	5.16	5.90	3.015

The depth on crest has not been corrected to eliminate velocity of approach.

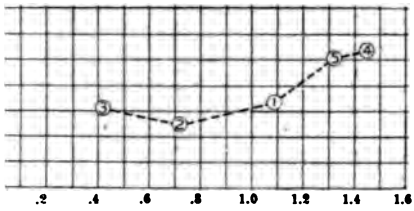
OTTAWA RIVER DAM, CANADA.

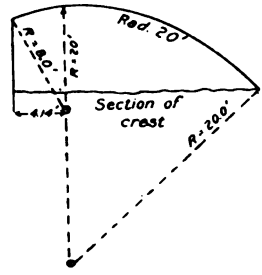
Data by T. C. Clark, C. E. Dam 30 feet high, with upstream and downstream faces planked and sloping 3:1, forming sharp crest angle at junction.

Discharge data for Ottawa River dam.

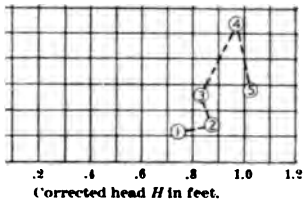
Length of dam, in feet.	Depth on crest, in feet.	Discharge, in cubic feet per second.	Discharge coefficient C.
1,600	2.5	26,000	4.106
1,760	10.0	190,000	3.408

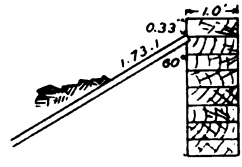
These data are notable as giving the only authentic value of discharge over a dam under so great a head as 10 feet. The high coefficient found for a head of 2.5 feet renders the results somewhat doubtful.



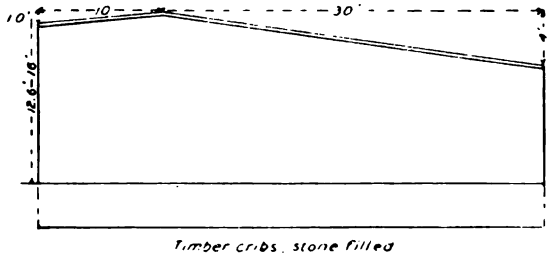


TAYLOR-HOWARD EXPERIMENTS ON DAM AT AUSTIN, TEX.

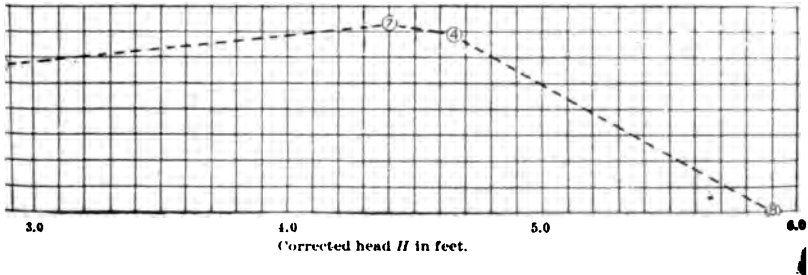




EXPERIMENTS OF DWIGHT PORTER, BLACKSTONE RIVER, ALBION, MASS.



Timber cribs, stone filled



MUSKINGUM RIVER DAM. DATA BY MAJ. W. H. BIXBY, U. S. A.

EXPERIMENTS TO DETERMINE COEFFICIENT C FROM ACTUAL DAMS.

AUSTIN, TEX., DAM.[a]

A series of current-meter measurements of the discharge over this dam were made in January and March, 1900. Several observations at each depth have been combined. The resulting mean coefficients are given in the following table:

Discharge coefficients for the Austin, Tex., dam.

Date.	Number.	H	H=depth at crest of dam.	Range of variation of C. From—	Range of variation of C. To—	Number of determinations.	Average value of C.
1900.							
Jan. 15	1	1.09	0.838	3.09	3.14	4	3.132
Jan. 18	2	.72	.625	3.00	3.11	11	3.053
Jan. 26	3	.42	.33	3.06	3.13	4	3.112
Mar. 28	4	1.44	1.04	3.32	3.36	3	3.333
Mar. 28	5	1.32	.96	3.26	3.33	5	3.302
Average							3.186

ROUGHNESS OF CREST.

The models used in weir experiments have usually been constructed of planed and matched timber. In actual dams a wide variety of conditions exist, including, in the order of roughness, sheet-steel crests, boards smoothed by wear and rendered slippery by water soaking and fungus growths, unplaned boards, dressed masonry, formed concrete, rubble and undressed ashlar, with earth, cobble, or broken-stone approaches. For the determination of the extent, if any, to which the coefficient applying for a smooth-crested dam must be modified to apply to any of these conditions, the following data are available.

UNITED STATES DEEP WATERWAYS, SERIES 7 AND 8 (PL. XVII).

Model dams, 4.9 feet high, 2:1 slope on both faces. The mean coefficients are about 1 per cent greater for crest of planed boards than for crest covered with one-fourth-inch mesh wire cloth.

[a] Taylor, T. U., the Austin dam: Water-Sup. and Irr. Paper No. 40, U. S. Geol. Survey, 1900, p. 33.

CROTON DAM, ROUND-CREST SECTION, MODEL A (PL. XIX).

Crest rounded, radius 10 feet. Upstream slope about 6:1.

Comparative coefficients with varying roughness, Croton round crest.

Series.....	1	1a	2	3
Head, in feet.	Smooth-pine crest.	Unplaned-plank crest and slope.[a]	Broken-stone slope, unplaned crest.	Broken-stone slope, wire cloth on crest.
0.25	3.34	2.84	3.18	3.16
.50	3.24	2.91	3.18	3.09
1.00	3.21	3.04	3.19	3.15
1.50	3.21	3.12	3.20	3.15
2.00	3.21	3.15	3.21	3.15
2.50	3.21	3.15	3.22	3.15
3.00	3.21	.....	3.22	3.15

[a] This series appears doubtful.—R. E. H.

CROTON DAM, ANGULAR SECTION, MODEL B (PL. XX).

Apron slope 1.25:1, upstream slope 6.24:1 for 13 feet, then roug and slope about 4:1 to bottom.

Comparative coefficients, varying roughness, Croton angular crest.

Series. / Head.	Unplaned plank.	Unplaned plank, rough-stone approach.	Rough-stone approach, wire cloth on crest.
0.25	3.61	.....	3.56
.50	3.63	3.66	3.57
1.00	3.67	3.66	3.58
1.50	3.68	3.66	3.60
2.00	3.70	3.66	3.61
2.50	3.70	3.66	3.62

The data given above are somewhat discordant, but indicate that general the decrease in discharge resulting from the roughness of t various materials forming the crests and approaches of dams will r exceed from 1 to 2 per cent for low heads, and usually decreases the depth of overflow increases.

FALLS.

Bellasis[a] presents the following analysis for a fall in which there is either a raised weir nor a lateral reduction in section. If v is the mean velocity at CD, near to AB, then v is both the velocity of approach and the velocity in the weir formula

$$v=\frac{2}{3}\,c\sqrt{2g\left(D+\alpha\frac{v^2}{2g}\right)},$$

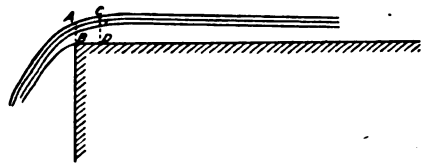


FIG. 10.—Fall.

here c is a coefficient of velocity.

$$v^2=\frac{4}{9}\,c^2\,2gD+\frac{4}{9}\,\alpha c^2 v^2$$

$$\left(1-\frac{4}{9}\,\alpha c^2\right)v^2=\frac{4}{9}\,c^2\,2gD$$

$$v=\frac{\frac{2}{3}\,c\sqrt{2gD}}{\sqrt{1-\frac{4}{9}\,\alpha c^2}}$$

Making $\alpha=1.00$ and $c=0.79$.

$$v=\frac{3.424\,\sqrt{D}}{\sqrt{1-0.277}}=4.74\,\sqrt{D} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (72)$$

$$Q=vDL=4.74\,LD^{\frac{3}{2}}$$

The depth D is to be measured so near AB that the water shall have acquired its velocity of efflux. The depth will, of course, be affected by the surface curve, the upstream extension of which will be longer according as the slope of the leading channel is flatter, being very great for a horizontal channel. The formula needs experimental verification, but affords a convenient basis of approximation of the flow through troughs and sluices and over aprons and falls.

Experimental data for c are needed.

[a] Hydraulics, p. 99.

WEIR CURVED IN PLAN.

Milldams of both wood and masonry are often constructed to bow upstream, sometimes to secure the added strength of arched form, or to secure additional spillway length, or to follow the crest of a favorable rock ledge, or to throw the ice-bearing current away from intake gates. The dam may follow the arc of a circle, or, as is common with timber dams, there may be an abrupt angle in the plan of the dam. Fig. 11 shows a graphical comparison of curved and angle dams with a straight dam across the same channel, the former being each 13.5 per cent longer than the straight crested dam.

If such an arched spillway opens out of a broad, deep pond, the discharge over it would be greater than for a straight overfall very nearly in proportion to the excess in length of the arc as compared with the length of its chord.

When the stream is confined in a restricted channel, the increased velocity of approach above the longer spillway will become a factor. Thus if two dams—one straight, the other arched—were placed in the same straight, uniform channel, and the depth on crest measured at the same distance upstream from each, then, with the same measured head on both, the velocity of approach to the arched dam would be

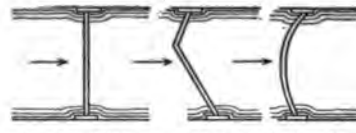


FIG. 11.—Weir curved or angular in plan.

greater nearly in the same proportion that its length of crest and discharge are greater than for the straight crest. Properly corrected for velocity of approach, the arched dam will give a correct measurement of the discharge, the length of the arc being used as the crest length. When the length of the arc greatly exceeds the channel width, the velocity of approach may become excessive, introducing uncertainty as to the proper correction coefficient, difficulty in measuring the head, and an uplifting of the central swifter-flowing portion of the stream surface.

The circular overflow lip of a vertical artesian-well casing is sometimes used to approximate the flow, the measured depth of water above the lip of the pipe, together with its circumference, being used in the weir formula.[a]

[a] Experiments showing the discharge over a circular weir to be proportional to the length of the arc were made by Simpson at Chew Magna, Somersetshire, England, 1850, not recorded in detail.

SUBMERGED WEIRS.

THEORETICAL FORMULA.

ı a "submerged," "drowned," "incomplete," or "partial" weir the
ɜr on the downstream side stands above the crest level.
he submerged weir is not extensively used as a device for stream
ng. A knowledge of the relations of head, rise, and discharge
uch weirs is, however, of great importance in works of river
rovement, canals, etc., and the leading formulas are here presented.
may be added that for situations where head can not be sacrificed,
luding the use of an ordinary weir, and where the velocity is not
ntinuous function of the depth, as in race ways, making a channel-
ıg curve inapplicable, the use of submerged weirs to measure or
rol the discharge merits consideration. Their use for such pur-
s as the equable division and distribution of water in power canals
hitherto been very restricted, owing to the lack of experimental
icients.

ɜt H = Head on upstream side, corrected for velocity of approach.
D = Measured head, upstream side of weir.
d = Measured head, downstream side of weir, or the depth of drowning, taken below the ressault.
Z = Difference of elevation, upstream and downstream sides $= H - d$.
P = Height of weir above channel bottom.
L = Length of weir crest, feet.
v = Mean velocity of approach.
$\triangle$ = Head on a thin-edged weir that would give the same discharge.
M' and C' coefficients of discharge for a submerged weir.

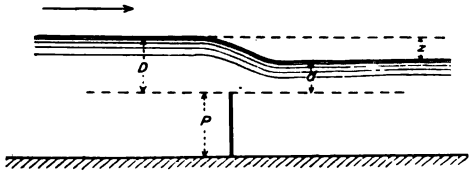


FIG. 12.—Submerged weir.

ıe theoretical formula of Dubuat for discharge is obtained by
ɹrding the overflow as composed of two portions, one through the
er part $D-d$, treated as free discharge, the other through the
ɜr part d, treated as flow through a submerged orifice.
ombining the two discharges,

$$Q = Q_1 + Q_2 = \frac{2}{3}\sqrt{2g}\,L(D-d)^{\frac{3}{2}} + Ld\sqrt{2g(D-d)}$$

By reducing, including a coefficient, and using the head H corrected for velocity of approach, we have the general formula for a submerged weir.

$$Q=\frac{2}{3}M'L\sqrt{2gZ}\left(H+\frac{d}{2}\right)=C'L\left(H+\frac{d}{2}\right)\sqrt{Z} \quad . \quad . \quad . \quad (73)$$

The head due to the velocity of retreat should in strictness be subtracted from the depth of submergence d. This is not commonly done, however, in the experiments, where the usual method of producing the submergence is by damming and retarding the water below. In practice, if the velocity of retreat is large, the correction should be made.

The theory of formula (73) makes $C'=1.5$ times the value of the coefficient C in the free portion of the discharge.[a] This value is adopted by Dubuat and Weisbach.

D'Aubuisson gives $C'=1.43C$.

Francis's early experiments make $C'=1.38C$.

From gage records of large rock-filled crib dams on Kentucky River, having planked upstream slope 3:1 and vertical steps below crest—height of dams about 20 feet, heads 4 to 7.5 feet, mean 5.3 feet—Nelles found results as follows:

Dam No. 3, water falling slowly 4 days,	$C'=1.5C$.
Dam No. 2, water falling slowly 3 days,	$C'=1.53C$.
Dam No. 1, water rising and falling slowly 5 days,	$C'=1.46C$.

FTELEY AND STEARNS SUBMERGED-WEIR FORMULA.[b]

Fteley and Stearns use the base formula

$$Q=CL\left(H+\frac{d}{2}\right)\sqrt{Z} \quad . \quad . \quad . \quad . \quad . \quad . \quad (74)$$

Coefficients for the above formula were derived from experiments on thin-edged weirs, by Fteley and Stearns and by J. B. Francis, and give correct results for weirs for which the free discharge would be correctly calculated by the Francis formula.

The head on upstream side varied from 0.3251 to 0.9704 foot, and $\frac{d}{H}$ varied from -0.063 to 0.081 with air under nappe, and from 0.077 to 0.975 with no air under nappe, and in applying the formula the same conditions should be complied with. The authors comment that where sufficient head can not be obtained for a weir of the usual free-discharge type, a submerged weir may be used, provided that the head does not vary greatly.

[a] See valuable discussion of submerged weirs by Geo. T. Nelles in Trans. Am. Soc. C. E., vol. 46, pp. 359–383.

[b] Fteley and Stearns, Experiments on the flow of water, etc.: Trans. Am. Soc. C. E., vol. 12, pp. 101–108.

om a large-scale curve Fteley and Stearns derive the following : of coefficient C, for formula (74):

Fteley and Stearns's coefficients for submerged weirs.

0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
.....	3.330	3.331	3.335	3.343	3.360	3.368	3.371	3.372	3.370
3.365	3.359	3.352	3.343	3.335	3.327	3.318	3.310	3.302	3.294
3.286	3.278	3.271	3.264	3.256	3.249	3.241	3.234	3.227	3.220
3.214	3.207	3.201	3.194	3.188	3.182	3.176	3.170	3.165	3.159
3.155	3.150	3.145	3.140	3.135	3.131	3.127	3.123	3.119	3.116
3.113	3.110	3.107	3.104	3.102	3.100	3.098	3.096	3.095	3.093
3.092	3.091	3.090	3.090	3.089	3.089	3.089	3.090	3.090	3.091
3.092	3.093	3.095	3.097	3.099	3.102	3.105	3.109	3.113	3.117
3.122	3.127	3.131	3.137	3.143	3.150	3.156	3.164	3.172	3.181
3.190	3.200	3.209	3.221	3.233	3.247	3.262	3.280	3.300	3.325

here $\frac{d}{H}$ is less than 0.15 Q is not sensibly affected by submergence.

here $\frac{d}{H}$ is from 0.5 to 0.8 C may be taken at 3.10.

orrection for velocity of approach was made by the formula $D+\frac{v^2}{2g}$. No correction was made for velocity of retreat.

ie formula is probably applicable to larger dams and greater depths electing proper values of C, $\frac{d}{H}$ being a relative quantity.

number of empirical formulæ for submerged-weir discharge are used.

CLEMENS HERSCHEL'S FORMULA.[a]

erschel's formula, based on experiments of J. B. Francis, 1848, ey and Stearns, 1877, and J. B. Francis, 1883, is

$$Q=3.33\ L(NH)^{\frac{3}{2}}=3.33\ L\triangle^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad (75)$$

this formula the measured head[b] is reduced to an equivalent head would give the same discharge over a free overflow. The value of coefficient $N=\frac{\triangle}{H}$ depends on the proportional submergence $\frac{d}{H}$.

rshel, Clemen, The problem of the submerged weir: Trans. Am. Soc. C. E., vol. 14, May, 1885, 1-196.

rected for velocity of approach by method for Francis's formula before applying in above la.

The values of this ratio, together with their probable error, are ıven below.

Coefficient N, Herschel's submerged-weir formula. [a]

$\frac{d}{D}$	0.0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
.0	1.000	1.004	1.006	1.006	1.007	1.007	1.007	1.006	1.006	1.005
.1	1.005	1.003	1.002	1.000	.998	.996	.994	.992	.989	.987
.2	.985	.982	.980	.977	.975	.972	.970	.967	.964	.961
.3	.959	.956	.953	.950	.947	.944	.941	.938	.935	.932
.4	.929	.926	.922	.919	.915	.912	.908	.904	.900	.896
.5	.892	.888	.884	.880	.875	.871	.866	.861	.856	.851
.6	.846	.841	.836	.830	.824	.818	.813	.806	.800	.794
.7	.787	.780	.773	.766	.758	.750	.742	.732	.723	.714
.8	.703	.692	.681	.669	.656	.644	.631	.618	.604	.590
.9	.574	.557	.539	.520	.498	.471	.441	.402	.352	.275

[a] Values for $\frac{d}{D}$ exceeding 0.80 less accurately determined.

$\frac{d}{D}$=0.02 to 0.14, variation of $N=\pm0.005$ to 0.007.
=0.15 to 0.22, variation of $N=\pm0.008$ to 0.010.
=0.24 to 0,32, variation of $N=\pm0.012$ to 0.014.
=0.33 to 0.41, variation of $N=\pm0.015$ to 0.017.
=0.42 to 0.59, variation of $N=\pm0.018$.
=0.60 to 0.65, variation of $N=\pm0.017$ to 0.015.
=0.66 to .071, variation of $N=\pm0.014$ to 0.012.
=0.72 to .084, variation of $N=\pm0.011$ to 0.009.

This table indicates that for depths of submergence not exceeding 20 per cent, the head will not ordinarily be increased more than 2 per cent.

The discharge over a submerged weir, according to Herschel's formula, bears the ratio $N^{\frac{3}{2}}$ to that over an unsubmerged weir under the same head.

THE CHANOINE AND MARY FORMULA.

$$Q=M'LH\sqrt{2gZ} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (76)$$

This expression has a form similar to that for the ordinary formula for submerged orifices. It is applicable only under conditions identical with those for which M' has been determined.[a]

[a] Van Nostrand's Eng. Mag., vol. 34, p. 176.

R. H. RHIND'S FORMULA.[a]

$$Q=M'L\sqrt{2g}\left[d\sqrt{Z+0.01v^2}+\frac{2}{3}Z\sqrt{Z+0.035v^2}\right] \quad . \quad . \quad (77)$$

This may be reduced to the theoretical formula (73) by omitting the correction for velocity of approach.

BAZIN'S FORMULAS.[b]

By duplicating, with various depths of submergence, his experiments on thin-edged weirs Bazin deduced the following expressions for the coefficients for submerged weirs to be applied in the discharge formula

$$Q=m'\,LD\sqrt{2gD}.$$

Let P represent, as heretofore, the height of weir crest above channel bottom, the coefficient m being that which would apply to the same weir with free discharge.

(1) Accurate formula with small values of d:

$$m'=m\left[1.06+0.16\left(\frac{d}{P}-0.05\right)\frac{P}{D}\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad (78)$$

(2) Accurate formula with large values of d:

$$m'=m\left[\left(1.08+0.18\frac{d}{P}\right)\sqrt[3]{\frac{D-d}{D}}\right] \quad . \quad . \quad . \quad . \quad . \quad (79)$$

(3) Approximate formula for all cases:

$$m'=m\left(1.05+0.21\frac{D}{P}\right)\sqrt[3]{\frac{D-d}{D}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (80)$$

The above formulas are for weirs without end contractions.

The coefficient m contains the correction for velocity of approach of the free-discharge weir, and m' contains the necessary factor (if any) for the resulting modification of the velocity of approach effect, when the weir becomes drowned. They are only strictly accurate, therefore, when m' is substituted for m in Bazin's formula.

In Bazin's formulas the height P of the weir enters as a controlling factor in (1), and is present less prominently in (2) and (3).

The modification by drowning is made to depend on $\frac{d}{P}$ in (2), and on this ratio and that of the cube root of $\frac{D-d}{D}$ jointly in formula (3). It is often difficult to determine P or to apply these formulas to a weir fed by a large pond and having end contractions.

[a] Proc. Inst. Civil Engineers, 1886.

[b] Bazin, H., Expériences nouvelles sur l'écoulement en déversoir, 6me art., Ann. Ponts et Chaussées, Mémoires et Documents, 1898.

Assume $P=\infty$

Then (2) becomes

$$m'=m\times 1.08\sqrt[3]{\frac{D-d}{D}}=m\times 1.08\sqrt[3]{\frac{Z}{H}} \quad . \quad . \quad . \quad . \quad (81)$$

and differs from (3) when similarly reduced only in the substitution of 1.05 for 1.08 as a coefficient.

Ex. $D=4'$ $d=2'$ $P=\infty$

If $m=0.425$

$$m'=0.425\times 1.08\sqrt[3]{\frac{2}{4}}=0.364,$$

the discharge being 89.4 per cent of that over an unsubmerged weir under the same head.

Comparison of submerged-weir formulas.[a]

d, feet	.25	.50	.75	.25	.50	.75
H, feet	2.0	2.0	2.0	1.0	1.0	1.0
d/H	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
	Percentage of unsubmerged-weir discharge.					
Fteley-Stearns	99.91	95.06	89.29	95.01	82.61	64.02
Herschel	100.15	95.83	90.56	95.83	84.24	64.95
Bazin (3)	100.43	95.40	89.78	95.40	83.34	66.15

[a] Weir assumed to be very high so that there is no velocity of approach or of retreat. The coefficient of discharge for a thin-edged weir with free discharge has been taken at 3.33 for the Fteley-Stearns and Herschel formulas.

INCREASE OF HEAD BY SUBMERGED WEIRS.

Any of the submerged-weir formulas may be transformed into expressions giving the rise in water level caused by the construction of a submerged weir in a channel or canal; in this form they are most useful in the design of slack-water navigation works.

RANKINE'S FORMULAS.[a]

Weir not drowned, with flat or slightly rounded crest:

$$H=\triangle=\sqrt[3]{\frac{Q^2}{7L^2}}, \text{ approximate} \quad . \quad . \quad . \quad . \quad . \quad (82)$$

Weir drowned:

First approximation—

$$H'=\triangle+d$$

Second approximation—

$$H=H'-d\left(1-\frac{5}{4}\frac{d}{H'-d}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (83)$$

[a] Civil Engineering, p. 689.

COLONEL DYAS'S FORMULA.[a]

This is intended to determine the height of a weir on the crest of a fall in an irrigation or other canal to maintain a desired uniform depth and slope.

D = Depth on weir, feet.
X = Depth of uniform channel, feet.
$P = X - D$ = Height of weir necessary.
A = Area uniform channel section, feet.
R = Hydraulic radius, feet.
S = Slope or fall in feet, per foot.
L = Length of weir crest, feet.

$$D = \left(\frac{900 A^2 R S}{L^2}\right)^{\frac{1}{3}} - 125.8122 R S \quad . \quad . \quad . \quad . \quad (84)$$

If $A = 1000$ $X = 10'$ $R = 8.33$ $S = 0.001$ $L = 100$,

$$D = \left[\frac{900 \times 1000^2 \times 8.33 \times 0.001}{10000}\right]^{\frac{1}{3}} - 125.81 \times 8.33 \times 0.001$$

$$= 9.0856 - 1.0441 = 8.04$$

$$P = 10 - 8.04 = 1.96 \text{ feet.}$$

In this case length of weir equals width of channel, and the velocity of approach would be the mean velocity, which by Kutter's formula will vary, say, from 8 to 10 feet per second under the conditions, depending on the value of the coefficient of roughness n. This would make the flow in the channel 8,000 to 10,000 cubic feet per second.

As a check on the calculated depth D, it will be found that the flow over a weir 100 feet long under a head 8.04 feet (corrected for the large velocity of approach) will also be from, say, 8,000 to 10,000 cubic feet per second, depending upon the coefficient used in the weir formula.

SUBMERGED WEIRS OF IRREGULAR SECTION.

For certain forms of irregular weirs having vertical downstream faces, the discharge when subject to submergence may probably be approximated by applying the ratio of drowned to free discharge for a thin-edged weir similarly submerged as a correction to the coefficient for free discharge over the weir in question. For broad-crested weirs or weirs with aprons this method probably will not be applicable.

BAZIN'S EXPERIMENTS.

For many of the model weirs of irregular section for which free-discharge coefficients were obtained by Bazin, duplicate series of coefficients with various degrees of submergence were also obtained.

[a] Wilson, H. M., *Irrigation in India*: Twelfth Ann. Rept. U. S. Geol. Survey, 1890-91, pt. 2, p. 482.

Many of these data have been reduced to English units by Nelles.[a] Evidently each form of weir section will require a special formula or table of coefficients, and little more can be done than to refer to the original data for each specific case.

By way of general illustration of the character of submergence effect on weirs of irregular section, the writer has deduced the following roughly approximate formulas from Bazin's experiments on triangular weirs with vertical upstream faces and sloping aprons. The weirs were 2.46 feet high and the end contractions were suppressed. Coefficient curves for free discharge are given on Pl. V.

Three series are included:

Series 195, batter of face 1 : 1.
Series 196, batter of face 2 : 1.
Series 197, batter of face 5 : 1.

Experiments in which the proportional submergence $\frac{d}{D}$ was nearly the same were grouped, and the average values of $\triangle$, D, and d were determined. From these the mean values of $\frac{\triangle}{D}$ and $\frac{d}{D}$ were computed and platted and a straight-line formula deduced.

$$\left.\begin{aligned}\frac{\triangle}{D}&=0.72+b\left(1-\frac{d}{D}\right)\\ b&=0.08+0.17B.\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (85)$$

The initial effect occurs when

$$\frac{d}{D}=\frac{0.17B-0.20}{17B+0.08} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (86)$$

In the above formulas $\triangle$ is the *measured* head on a weir with free overflow, having the same form of cross section, that would give the same discharge. D is the depth on the submerged weir, d is the depth of submergence, and B is the batter or slope of the apron.

DATA CONCERNING EAST INDIAN WEIRS.

The following data compiled by Nelles[b] are derived from observations on actual dams under heads unusually great. The calculated coefficients in the ordinary weir formula (a)

$$Q=M'LH\sqrt{2gH},$$

in the theoretical submerged-weir formula (b)

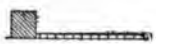
$$Q=M'L\sqrt{2g}Z\left(d+\frac{2}{3}Z\right),$$

and in the Rhind formula (77) are given in columns 14, 13, and 12, respectively (p. 145), the observed head being corrected for velocity of approach.

[a] Trans. Am. Soc. C. E., vol. 44, pp. 359-383.

[b] Loc. cit.

Data of submerged flow at certain large masonry dams in India.

Name of river.	Name of weir.	Make-up of weir. Description of parts.	Length of parts, in feet.	Depth of crest below water surface in— Upper pool, feet.	Lower pool, feet.	Observed fall over weir, feet.	Mean surface velocity of approach, in feet per second.	Corresponding velocity of head, feet.	Calculated discharge, in cubic feet per second.	Height of main body of weir, feet.	Coefficients of discharge in the various submerged-flow formulas. Rhind's (77).	Formula b, observed head. Submerged weir.	Formula a, observed head. Free weir.	Approximate section of weir.
			L	D	d	$D-d=z$	v	$\frac{v^2}{2g}$	Q	p				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Brahmini	Pattia	Main body	665	19.21	18.35	0.86	7.84	0.96	114,000	.....	0.881	0.806	0.241	Fig. 13.
		First step	60	8.21	7.35									
		Second step	9	2.21	1.35									
Byturnee	Byturnee	Sluices	100	18.10	15.29	2.81	.....	.....	Total, 260,000	7.9	0.953	0.940	0.491	
		Piers	14	7.68	4.87									
		Main body	912	10.84	8.03									
		Total overfall	1,026	.....	.....	.....	1.13	8.51	For main body alone, 212,400	7.9	0.979	0.970	0.511	 Fig. 14.
Do	Burrah	Seines	100	18.60	15.20	3.40	.....	.....						
		Piers	14	8.18	4.78									
		Main body	412	11.34	7.94									
		Total overfall	526	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Brahmini	Brahmini	Sluices	389	18.02	17.55	0.47	6.99	0.76	.....	7.5	.....	.....	.....	Same as Fig. 13.
		Piers	140	8.02	7.55									
		Main body	3,471	10.52	10.05				260,000		0.878	0.790	0.266	
		Total overfall	4,000	.....	.....	.....	.....	.....	307,500	.....	0.876	0.786	0.245	
Manhanuddy	Kajooree	Sluices	90	30.675	30.15	0.525	11.62	2.10	.....	10.65	.....	.....	.....	Do.
		Breaches	324	25.615	25.09									
		Main body	3,433	20.115	19.59				680,000		0.893	0.764	0.261	
		Total overfall	3,847	.....	.....	.....	.....	.....	787,000	.....	0.891	0.763	0.355	
Do	Manhanuddy	Shore sluices	190	17.45	15.45	2.00	7.74	0.93	.....	6.0	.....	.....	.....	Do.
		Center sluices	460	17.20	15.20									
		Main body	5,696	11.45	9.45				488,000		0.595	0.561	0.265	
		Total overfall	6,346	.....	.....	.....	.....	.....	609,000	.....	0.633	0.597	0.274	
Do	Beropa	Sluices	255	13.30	12.10	1.20	6.65	0.68	.....	5.0	.....	.....	.....	Do.
		Piers	118	4.30	3.10									
		Main body	1,607	8.30	7.10				82,800		0.594	0.570	0.244	
		Total overfall	1,980	.....	.....	.....	.....	.....	112,700	.....	0.648	0.677	0.260	

UNITED STATES DEEP WATERWAYS EXPERIMENTS.[a]

These experiments were made in 1899 at Cornell University hyc lic laboratory on a model having completely rounded profile, bei design for a submerged dam for regulation of Lake Erie.

The coefficient curve for free discharge is given on Pl. XVI. absolute coefficients and the relative discharge with various degree submergence are shown below. The Francis formula is used.

$$Q = C' L H^{\frac{3}{2}}.$$

Absolute coefficients.

D	Submergence from backwater.	C'
Feet.	*Feet.*	
0.0	0.00	3.70
.1	.66	3.67
.2	1.32	3.64
.3	1.98	3.60
.4	2.64	3.54
.5	3.30	3.47
.6	3.99	3.36
.7	4.62	3.17
.8	5.28	2.88
.9	5.94	2.30

Relative coefficients, United States Deep Waterways submerged-weir model.

$\frac{d}{H}$	$\frac{C'}{C}$	$\frac{h}{H}$	$\frac{C'}{C}$
0.0	1.000	0.5	0.937
.1	.991	.6	.907
.2	.983	.7	.856
.3	.972	.8	.778
.4	.956	.9	.621
		1.0	

C is the coefficient for free discharge over a similar weir unde same head.

WEIR DISCHARGE UNDER VARYING HEAD.

Problems of weir discharge under varying head occur in the de of storage reservoirs for river regulation, and in determining the n mum discharge of streams.

[a] Rept. U. S. Board of Engineers on Deep Waterways, pt. 1, p. 291.

An effort has been made in the present chapter to record the various working formulas resulting from the solution of this mathematically difficult portion of the theory of the weir, and to give numerical data to facilitate calculations.

It is assumed that there is no velocity of approach, or, if any, that the head has been corrected therefor. The weir coefficient is also assumed to continue constant through the range of variation of the head.

Notation:

T = Time in seconds required for the head to change between two assigned values.
H_o = Initial depth on weir, feet.
H_t = Depth on weir at the time t.
S = Reservoir surface area, square feet.
L = Length of overflow weir, feet.
I = Rate of inflow to reservoir, cubic feet per second.
Q = Rate of outflow at time t.

PRISMATIC RESERVOIR, NO INFLOW, TIME REQUIRED TO LOWER WATER SURFACE FROM H_o TO H_t.[a]

$$dQ = CLH^{\frac{3}{2}}dt = -SdH$$

$$dt = -\frac{S}{CLH^{\frac{3}{2}}}dH$$

$$\int_0^T dt = -\frac{S}{CL}\int_{H_o}^{H_t} H^{-\frac{3}{2}}dH$$

$$T = \frac{2S}{CL}\left(\frac{1}{\sqrt{H_t}} - \frac{1}{\sqrt{H_o}}\right) \quad . \quad . \quad . \quad . \quad . \quad (87)$$

Where $C = \frac{2}{3}M\sqrt{2g} = 5.35\ M$

$T = \infty$, when $H_t = 0$.

If $S = 1{,}000{,}000$, $H_o = 4$, $H_t = 0.1$, $C = 3.33$, and $L = 100$,

$$T = \frac{2}{100} \times \frac{3{,}000{,}000}{10}\left(\frac{\sqrt{10}}{1} - \frac{1}{2}\right) = 15{,}972 \text{ seconds} = 4.44 \text{ hours.}$$

To lower the reservoir from $H = 4$ to $H = 1$ would require 3,000 seconds.

APPROXIMATE TIME OF LOWERING PRISMATIC OR NONPRISMATIC RESERVOIR.

Choosing small successive values of $H_o - H_t$, we may solve this problem approximately, as shown in the following table:

$$\text{Time required to lower reservoir from } H_o \text{ to } H_t = \frac{(H_o - H_t)}{\text{Mean } Q}\frac{S}{} \quad (88)$$

[a] Des Ingenieurs Taschenbuch, I, 1902, p. 230.

We may take the mean discharge between the narrow limits H_o and H_t,

$$Q_m = \frac{CL}{2}\left(H_o^{\frac{3}{2}} + H_t^{\frac{3}{2}}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (89)$$

or, using the average head,

$$Q_m = CL\left(\frac{H_o + H_t}{2}\right)^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (90)$$

In the following example we have used the latter value, and have made $H_o - H_t = 0.5$ foot. A similar solution may be made for a non-prismatic reservoir, using successive values of $\frac{S_1 + S_2}{2}$ as the reservoir area, and determining the increments of T by formula (88).

Example of varying discharge.

H_o	H_t	Average H	Q per second.	$\frac{1000}{Q}$	T for increment $H_o - H_t$.	Total T, in seconds.
4.0	3.5	3.75	2,417.0	0.4137	207	207
3.5	3.0	3.25	1,951.0	.5126	256	463
3.0	2.5	2.75	1,519.0	.6580	330	793
2.5	2.0	2.25	1,124.0	.8970	448	1,241
2.0	1.5	1.75	771.0	1.2970	650	1,891
1.5	1.0	1.25	465.4	2.1500	1,070	2,961

The total time required in seconds is 2,961, as compared with 3,000 by formula (87).

The time required, using the average Q instead of the average H in the calculation, that is, using formula (89) instead of (90), is 2,933.5 seconds.

The time T is directly proportional to the area of storage surface and inversely proportional to the length of spillway. It is also usually proportional to the value of C in the weir formula.

RESERVOIR PRISMATIC, WITH UNIFORM INFLOW.[a]

GENERAL FORMULAS.

Starting with reservoir full to crest level, $H_o = 0$, to find the time required for the depth of overflow to reach a given stage, H_t.

[a] Mullins, Lieut. Gen. J., Irrigation Manual, Madras Govt., 1890, App. V, pp. 214-223.

When individual values of the increment H_2-H_1 are small, not over .5 foot each, if successive values are taken, we have approximately:

$$t=\frac{S(H_2-H_1)}{I-\frac{Q_1+Q_2}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (91)$$

$$I=\frac{2(H_2-H_1)S+Q_1+Q_2}{2t} \quad . \quad . \quad . \quad . \quad . \quad (92)$$

=time required to rise through the increment H_2-H_1.

A summation of the successive values of t required for the water to rise each increment will give the total time of rise from H_o to H_t. Formula (92) will give the maximum run-off from a catchment area tributary to a reservoir if two successive values of H and the corresponding value of t are known.

Formula (92) may also be used to determine T for a nonprismatic reservoir with a variable rate of inflow by choosing such increments, H_2-H_1, that the average values of S, I, and Q will be nearly correct. Variations in the weir coefficient C may also be considered.

FORMULAS FOR TIME OF RISE TO ANY HEAD H, PRISMATIC RESERVOIR WITH UNIFORM INFLOW.

Several analytical solutions of this problem have been made. Starting at spillway level, let H_a equal the depth of overflow corresponding to the quantity of inflow I. The problem is stated by the following differential equation whose primitive is required:

(Rate inflow—rate outflow) $dt=d$ (increase in storage), or

$$(I-CLH^{\frac{3}{2}})\,dt=SdH \quad . \quad . \quad . \quad . \quad . \quad . \quad (93)$$

In the solution, mathematical substitutions are necessary in order to render the time-outflow equation integrable in known forms. A very clear demonstration for a special value of C has been given by Frizell.[a] By modifying Frizell's formula to adapt it to the use of any value of C in the weir formula, the following equation is obtained:

$$\frac{3CLb}{2S}T=\text{nat. log}\sqrt{\frac{H+b\sqrt{H}+b^2}{b-\sqrt{H}}}+\sqrt{3}\tan^{-1}\sqrt{\frac{1}{3}}-\sqrt{3}\tan^{-1}\frac{2\sqrt{H}+b}{b\sqrt{3}} \quad (94)$$

where $b=\sqrt[3]{\frac{I}{CL}}$

When $H=H_a$, the second member becomes the sum of an infinite and two finite quantities, T is then infinite, and the outflow can never

[a] Water Power, pp. 200-203.

become equal to the inflow, or H can never equal H_a, which quantity it approaches as a limit as T increases. Frizell places $H=rH_a$, r having any value less than unity, and, being very nearly unity, $\sqrt{r}$ will be more nearly so, and is taken as equal to unity, without great error, enabling the two inverse trigonometric constants to be evaluated in terms of arc, giving finally:

$$T=\frac{2S}{3(C^2L^2I)^{\frac{1}{2}}}\left(\text{nat. log.}\frac{\sqrt{1+\sqrt{r}+r}}{1-\sqrt{r}}-0.88625\right) \quad . \quad . \quad (95)$$

Nat. log $N=2.302585 \log_{10} N$

E. Ludlow Gould[a] gives the following formula, identical with the above except in the form of the constant of integration:

$$T=\frac{2S}{3(C^2L^2I)^{\frac{1}{2}}}\left[\text{nat. log}\frac{\sqrt{1+\sqrt{r}+r}}{1-\sqrt{r}}\right.$$

$$\left.-\sqrt{3}\left\{\tan^{-1}\frac{2}{\sqrt{3}}\left(\frac{1}{2}+\sqrt{r}\right)-\frac{\pi}{6}\right\}\right] \quad . \quad . \quad . \quad . \quad (96)$$

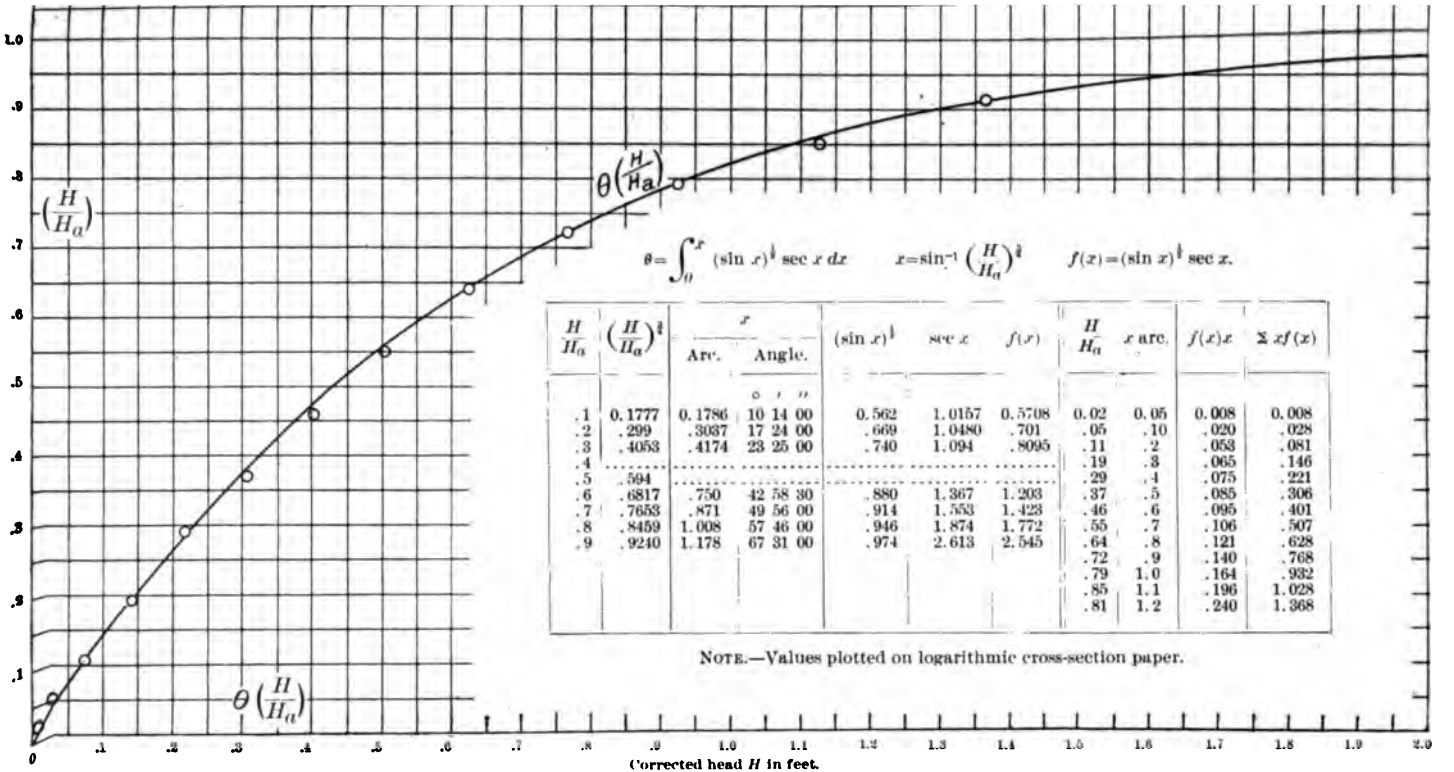
$r=\frac{H}{H_a}$ as before. Gould does not consider $\sqrt{r}$ constant, but derives the values of the function in brackets for various values of r, from which the following table has been derived:

$$\phi=\left[\text{nat. log}\frac{\sqrt{1+\sqrt{r}+r}}{1-\sqrt{r}}-\sqrt{3}\left\{\tan^{-1}\frac{2}{\sqrt{3}}\left(\frac{1}{2}+\sqrt{r}\right)-\frac{\pi}{6}\right\}\right] \quad . \quad (97)$$

Values of ϕ, Gould's formula.

$\frac{H}{H_a}$	0	1	2	3	4	5	6	7	8	9
0.0	0.0000	0.0153	0.0306	0.0459	0.0613	0.0766	0.0919	0.1072	0.1226	0.1378
.1	.1532	.16854	.1838	.1992	.2155	.2319	.2483	.2646	.2810	.2973
.2	.3137	.3301	.3464	.3628	.3791	.3955	.4137	.4319	.4501	.4683
.3	.4865	.5047	.5229	.5411	.5593	.5775	.5957	.6139	.6321	.6534
.4	.6747	.6960	.7173	.7386	.7598	.7811	.8024	.8237	.8450	.8663
.5	.8876	.9137	.9399	.9660	.9921	1.0183	1.0444	1.0705	1.0966	1.1128
.6	1.1489	1.1750	1.2012	1.2322	1.2674	1.3027	1.3380	1.3733	1.4086	1.4439
.7	1.4792	1.5145	1.5498	1.5851	1.6203	1.6556	1.7073	1.7590	1.8107	1.8624
.8	1.9141	1.9658	2.0176	2.0715	2.1488	2.2262	2.3035	2.3808	2.4582	2.5355
.9	2.6129	2.7681	2.9233	3.0785	3.2347	3.3889	3.5441	4.0096	4.4750	4.9405

[a] Engineering News, Dec. 5, 1901, pp. 430-431.



$$\theta = \int_0^x (\sin x)^{\frac{1}{2}} \sec x \, dx \qquad x = \sin^{-1}\left(\frac{H}{H_a}\right)^{\frac{1}{2}} \qquad f(x) = (\sin x)^{\frac{1}{2}} \sec x.$$

$\frac{H}{H_a}$	$\left(\frac{H}{H_a}\right)^{\frac{1}{2}}$	x Arc.	x Angle. ° ′ ″	$(\sin x)^{\frac{1}{2}}$	$\sec x$	$f(x)$	$\frac{H}{H_a}$	x arc.	$f(x)x$	$\Sigma\, xf(x)$
.1	0.1777	0.1786	10 14 00	0.562	1.0157	0.5708	0.02	0.05	0.008	0.008
.2	.299	.3037	17 24 00	.669	1.0480	.701	.05	.10	.020	.028
.3	.4053	.4174	23 25 00	.740	1.094	.8095	.11	.2	.053	.081
.4	.....	.....	.....	.....	.....	.....	.19	.3	.065	.146
.5	.594	.....	.....	.....	.....	.....	.29	.4	.075	.221
.6	.6817	.750	42 58 30	.880	1.367	1.203	.37	.5	.085	.306
.7	.7653	.871	49 56 00	.914	1.553	1.423	.46	.6	.095	.401
.8	.8459	1.008	57 46 00	.946	1.874	1.772	.55	.7	.106	.507
.9	.9240	1.178	67 31 00	.974	2.613	2.545	.64	.8	.121	.628
							.72	.9	.140	.768
							.79	1.0	.164	.932
							.85	1.1	.196	1.028
							.81	1.2	.240	1.368

NOTE.—Values plotted on logarithmic cross-section paper.

DIAGRAM OF VARIABLE DISCHARGE.

Ve may write formula (9)

$$T=\phi\left(\frac{H}{H_a}\right)\times\frac{2S}{3\sqrt[3]{C^2L^2I}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (98)$$

R. S. Woodward suggests the formula [a]

$$\left.\begin{aligned} T&=\frac{4S}{3\sqrt[3]{C^2L^2I}}\int_0^X(\sin X)^{\frac{1}{3}}\sec X dX \\ \text{ere}\qquad X&=\sin^{-1}\sqrt{\frac{CLH^{\frac{3}{2}}}{I}}=\sin^{-1}\left(\frac{H}{H_a}\right)^{\frac{3}{4}} \end{aligned}\right\} \quad . \quad . \quad . \quad (99)$$

This, like the preceding expressions, becomes infinity when the egral is carried over the entire range $X=0$ to $X=\frac{\pi}{2}$, conforming :h the physical conditions.

The writer has evaluated this function for finite values of $\frac{H}{H_a}$ mechanical quadrature, as shown in the diagram, Pl. XXXVIII. e diagram illustrates the rapid rise until a head closely approaching , is attained, occupying a comparatively short time interval, while · further increments of head the time interval is relatively very eat.

E. Sherman Gould [b] gives the same integral developed as an infinite ies

$$T=\frac{2SH}{I}\left[\frac{1}{2}+\frac{K}{5}+\frac{K^2}{8}+\cdots+\frac{K^n}{2+3_n}\right] \quad . \quad . \quad (100)$$

ere $$K=\left(\frac{H}{H_a}\right)^{\frac{3}{2}}.$$

If $$\vartheta\left(\frac{H}{H_a}\right)=\left[\frac{K^0}{2}+\frac{K^1}{5}+\frac{K^2}{8}+\cdots+\frac{K^n}{2+3_n}\right]$$

$$T=\frac{2SH}{I}\times\vartheta\left(\frac{H}{H_a}\right)=\frac{2S}{\sqrt[3]{C^2L^2I}}\vartheta\left(\frac{H}{H_a}\right) \quad . \quad (101)$$

[a] Engineering News, December 5, 1901, p. 431.
[b] Engineering News, November 14, 1901, pp. 362-363.

If we write

$$F=\frac{2S}{3\sqrt[3]{C^2L^2I}},$$

hen Frizell's formula may be written $T=F\times\rho\left(\frac{H}{H_a}\right)$

. L. Gould's formula may be written $T=F\times\phi\left(\frac{H}{H_a}\right)$

Woodward's formula may be written $T=2F\psi\left(\frac{H}{H_a}\right)$. (102)

. Sherman Gould's formula may be written $T=F\times\vartheta\left(\frac{H}{H_a}\right)$

The formulas are therefore identical, the transcendental factors earing the relation,

$$\rho\left(\frac{H}{H_a}\right)=\phi\left(\frac{H}{H_a}\right)=2\psi\left(\frac{H}{H_a}\right)=\vartheta\left(\frac{H}{H_a}\right)$$

The E. L. Gould, Woodward, and E. S. Gould formulas are applicable for any value of the ratio $\frac{H}{H_a}$. That of Frizell can be strictly pplied only when $\frac{H}{H_a}$ is nearly unity. In the E. S. Gould formula $\left(\frac{H}{H_a}\right)$ converges very slowly as the argument approaches unity.

For rough calculations E. S. Gould gives the rule

$$TI-TCL(\mu H)^{\frac{3}{2}}=SH$$

where μ is the coefficient in the weir formula for reducing final head to mean head.

$$T=\frac{SH}{I-CL(\mu H)^{\frac{3}{2}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (103)$$

The ratio μ of the constant mean head which would give the total discharge SH in the time T he finds by trial.

E. S. Gould gives the values

$\mu=0.67$ for small values of H
to $\mu=0.75$ for large values of H.

Comparing the formulas,

Let $S=1{,}000{,}000$ square feet

$C=3.33=\frac{10}{3}$

$L=100$

$I=10{,}000$ cubic feet per second

$H_a=\left(\frac{I}{CL}\right)^{\frac{2}{3}}=30^{\frac{2}{3}}=9.655$ feet.

Required the time to rise to a height $H_a=0.9H=8.6895$ feet.

$$F=\frac{2S}{3\sqrt[3]{C^2L^2I}}=643.5$$

Frizell	(95)	$T=1677.6$ seconds.
E. L. Gould	(96)	$T=1681.5$ seconds.
Woodward	(99)	$T=1660.2$ seconds.
E. S. Gould (approximate)	(103)	$T=1488.3$ seconds.

The difference in the value of T by the first three formulas represents the difference in the values of the transcendental portions of the equations as evaluated by different methods.

The time required to rise from H_a to H_b will be the difference of the times T_1 and T_2 by the above formulas.

NONPRISMATIC RESERVOIR, UNIFORM INFLOW.

P. P. L. O'CONNELL.[a]

Representing the reservoir by a cone having its apex at distance A, below plane of the overflow,

$$\left.\begin{array}{ll}\text{Area at overflow level} & =S_0=\pi(\alpha A)^2\\ \text{Area at any other level} & =S=\pi[\alpha(A+H)]^2\end{array}\right\} \quad \ldots\ldots \quad (104)$$

where α is the slope of the sides, or where there is α foot horizontal run to 1 foot vertical rise. From (104) with S_0 and α given, A may be determined.

Where the factor $\qquad I_1=\sqrt[3]{\frac{I}{CL}}$,

$$T=\frac{\pi\alpha^2}{CL}\left[-4A\sqrt{H}-\frac{2}{3}H^{\frac{3}{2}}-\frac{2}{3}I_1^3 \text{ nat. log}\frac{I_1^3-H^{\frac{3}{2}}}{I_1^3}\right.$$

$$-\frac{(2AI_1^2+A^2)}{3I_1} \text{ nat. log}\left(\frac{[\sqrt{H}-I_1]^2}{H+I_1\sqrt{H}+I_1^2}\right)$$

$$\left.+\frac{2A^2-4AI_1^2}{3I_1}\sqrt{3}\tan^{-1}\left(\frac{-\sqrt{3}H}{2I_1+\sqrt{H}}\right)\right] \quad . \; . \; (105)$$

[a] Mullins's Irrigation Manual.

E. L. GOULD.[a]

Calling i the angle of inclination of the banks, P_o the perimeter, at spillway level, exclusive of overflow,

$$S=S_o+BH+B_1H^2 \text{ where } B=P_o \cot i$$

$$B_1=\pi \cot i^2 \quad r=\frac{H}{H_1}$$

$$T=\frac{2}{3I^{\frac{1}{3}}C^2L^2}\Bigg[\left(S_o(CL)^{\frac{4}{3}}+B(ICL)^{\frac{2}{3}}\right)\text{nat. log}\,\frac{\sqrt{1+\sqrt{r}+r}}{1-\sqrt{r}}$$

$$-\left(S_o(CL)^{\frac{4}{3}}-B(ICL)^{\frac{2}{3}}\right)\sqrt{3}\left\{\tan^{-1}\frac{1+2\sqrt{r}}{\sqrt{3}}-\frac{\pi}{6}\right\}$$

$$-B_1I^{\frac{4}{3}}\left\{\text{nat. log}\,(1-r^{\frac{3}{2}})+r^{\frac{3}{2}}\right\}-B(ICL)^{\frac{2}{3}}\sqrt{r}\Bigg] \quad . \quad (106)$$

For $i=90°$ and $B=0$, the above formula reduces to (96), the equation for a prismatic reservoir.

VARIABLE INFLOW, NONPRISMATIC RESERVOIR.

This problem may be solved by dividing the reservoir into successive levels, and solving by the formulas previously given, as if each layer represented a portion of a reservoir with a constant inflow equal to the average rate, or if the formulas for prismatic reservoir are used, then each layer will be supposed to represent a portion of a prismatic reservoir of area equal to the average area of the layer.

Mullins's formula may often be more conveniently used and a better solution be obtained than by attempting to average the area and inflow, as would be necessary to apply the analytical formulas given.

The general differential equation for rise in time T with a variable inflow and reservoir area is

$$(I-Q)\,dT=SdH \quad . \quad . \quad . \quad . \quad . \quad . \quad (107)$$

If we can express I as a function of T, and S and Q as functions of H, and integrate between the limits $H=0$, $H=H_1$, we may obtain an equation between H and T similar to those given for prismatic reservoirs with constant inflow.

We may write the ordinary weir formula,

$$Q=CLH^{\frac{3}{2}}.$$

[a] Loc. cit.

The area S can usually be readily expressed in terms of the area at st level and slope of the reservoir sides (assumed constant within narrow limits 0, H); the inflow I often increases nearly as a linear ıction of T while a stream is rising rapidly; we have, then,

$$Q_t = CLH^{\frac{3}{2}}$$
$$S_t = S_o + 2\alpha\sqrt{S_o}H + \alpha^2 H^2$$
$$I_t = I_o + fT.$$

Substituting in (107)

$$\left(I_o + fT - CLH^{\frac{3}{2}} \right) dT = \left(S_o + 2\alpha\sqrt{S_o}H + \alpha^2 H^2 \right) dH \quad . \quad (108)$$

The complete primitive of this differential equation can be deter-ned only as an infinite series.[a]

Rivers during flood usually rise rapidly and fall slowly. The time-low function can sometimes be approximated by a modified sinusoid.

$$I = I_o + I_m \sin (bt)^{\frac{1}{n}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (109)$$

ıere $n =$ or > 1

T=Total duration of flood.

I_m=Maximum rate of inflow.

T_m=Time elapsed from beginning of rise to maximum.

The constants are so chosen that the arc value of the duration of e flood from stage I_o through to the same stage is π, or,

$$(bt)^{\frac{1}{n}} = \pi \qquad b = \frac{\pi^n}{T} \quad . \quad . \quad . \quad . \quad . \quad . \quad (110)$$

For the maximum we will have, differentiating (109),

$$\cos (bT_m)^{\frac{1}{n}} = 0, \qquad \text{or } (bT_m)^{\frac{1}{n}} = \frac{\pi}{2} \quad . \quad . \quad . \quad (111)$$

$$\text{or } b = \frac{1}{T_m}\left(\frac{\pi}{2}\right)^n = \frac{\pi^n}{T} \qquad \text{or} \qquad \frac{T}{T_m} = 2^n$$

$$n = \log \frac{T}{T_m} \times \frac{1}{\log 2} = 3.32204 \log \left(\frac{T}{T_m}\right) \quad . \quad . \quad . \quad (112)$$

ɔmmon logarithms being used.

If T=1000 and if T_m=200, then n=3.322 log 5=2.322,

$$b = \frac{\pi^{2.322}}{1000} = 0.0143, \text{ and } \frac{1}{n} = 0.43066$$

[a]Seddon, James A., C. E. (Proc. Am. Soc. C. E., vol. 24, June, 1898, pp. 559–598), has solved equation (108) for the Great Lakes reservoir system, assuming an annual cycle following the law $I = I_m + A$ n T, I_m being the mean inflow and T the time arc on a circle whose circumference represents one ear. He also assumes $Q = Q_o + bH$, or a linear function of the height H.

Example of variable flood discharge computed by formula (109).

t, in seconds.	(bt)	log (bt)	$\frac{1}{\log (bt)^n}$	$\frac{1}{(bt)^n}$	Angle.		$\frac{1}{\sin (bt)^n}$
					°	′	
100	1.43	0.155336	0.06695	1.1667	66	55	0.9199
200	2.86	.456366	.196694	1.573	90	00	1.0000
300	4.29	.632457	.27259	1.8732	107	21	.9938
400	5.72	.757396	.32644	2.1206	121	08	.8560
500	7.15	.854306	.36820	2.3346	133	49	.7216
600	8.58	.933487	.40233	2.5254	144	42	.5779
700	10.01	1.000434	.43100	2.6978	155	00	.3907
800	11.44	1.058426	.45618	2.8588	163	52	.2779
900	12.87	1.109578	.47790	3.0054	172	12	.1320

The form of the graph of the flood may be determined by plotting the quantities in the last column of this table in terms of t. The resulting curve rises rapidly to a maximum when $t=200$, after which it descends slowly.

TABLES FOR CALCULATIONS OF WEIR DISCHARGE.

The investigations at Cornell University have greatly extended the limit for which weir coefficients are definitely known. The experiments of Bazin did not reach beyond 1.8 feet head maximum. The tables of Francis for thin-edged weirs extended to a head of 3 feet.

The experiments at Cornell have furnished the coefficients for a variety of weir forms for heads up to 4, 5, and 6 feet. At such heads the nappe form has become stable for nearly all forms of weirs. We may now predict the probable extension of the coefficient curves for higher heads with more confidence than could be done by starting from a lower datum.

Owing to their usefulness in the approximate determination of flood discharges, the weir tables have been carried up to a head of 10 feet.

In the tables here given the head is uniformly expressed in feet. For computing the flow over irrigation modules and other small weirs where the head is measured in inches, weir tables expressed with the inch as the argument of head are convenient. Numerous tables of this character are available. The following may be referred to:

The Emerson weir tables, computed by Charla A. Adams, pages 251–285 of Emerson's Hydrodynamics, published by J. and W. Jolly, Holyoke, Mass. These give discharge in cubic feet per minute for weirs with two end contractions having lengths of 2, 3, 4, 5, 6, 7, 8, 10, 12, 16, and 20 feet. The discharge is computed by the Francis formula for heads from 0.001 foot to 2 feet, advancing by thousandths of a foot, with auxiliary table of decimal equivalents of fractional parts of inches.

The Measurement and Division of Water, Bulletin No. 27, Agricultural Experi-ıent Station, Fort Collins, Colo. This publication gives tables of discharge in cubic ·et per second, computed by the Francis formula, for a weir 1 foot long, for heads ı inches and sixteenths, from $\frac{1}{16}$ inch to 30 inches, with auxiliary table for end ontractions, and for velocity of approach correction by the Fteley and Stearns ule ($H=D+\frac{3}{2}h$). A similar weir table for a weir 1 inch long is given. Also a table f discharge for Cippoletti weirs ($C=3.36\frac{2}{3}$), for lengths of crest sill of 1, 1.5, 2, 3, 4, , and 10 feet. Head in inches and decimals with feet equivalents.

Special Instructions to Watermasters as to Measurements of Water, State Engineer's)ffice, Salt Lake City, Utah, 1896. Table of discharge, in cubic feet per second, for -foot crest, based on the Francis formula, with auxiliary table for end contractions ınd velocity of approach. The head is expressed in inches and thirty-seconds (with quivalents in feet) for $\frac{1}{32}$ inch to 36 inches. A similar table for heads in inches and ixteenths, from $\frac{1}{16}$ to 36 inches, gives the discharge in cubic feet per second by the 'rancis formula for weirs with two end contractions and for the crest lengths of 1, $1\frac{1}{2}$, ', $2\frac{1}{2}$, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12 feet. A table for trapezoidal weirs ($C=3.367$) ıf various crest lengths is also given.

California Hydrography, by J. B. Lippincott, Water-Supply Paper No. 81, United ·tates Geological Survey. This publication contains a table of weir discharge in ubic feet per second for heads, advancing by sixteenths, from $\frac{1}{16}$ inch to 10 inches with equivalent decimals of a foot), for weirs with two end contractions having rest lengths as follows: 4, 6, 9, 12, 15, and 18 inches, 2, 2.5, 3, 3.5, 4, 4.5, 5, 6, 7, 8, , 10, 12, 14, 16, 18, and 20 feet. Based on the Francis formula. Also published as circular.

The tables that follow are all original computations, with exception f the "Francis weir tables," page 162, and the table of head due to arious velocities, page 158.

TABLE 1.—HEAD DUE TO VARIOUS VELOCITIES.[a]

This table gives values of the expression

$$h=\frac{v^2}{2g},$$

ısed on the constant of gravity for the latitude and altitude of Lowell, ıass.,

$$g=32.1618,\ \frac{1}{2g}=0.01554639.$$

[a] Francis, Lowell Hydraulic Experiments, extended.

TABLE 1.—*Values of* $h=\frac{v^2}{2g}$, *or heads due to velocities from 0 to 4.99 feet per second.*

v	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001
.1	.0002	.0002	.0002	.0003	.0003	.0003	.0004	.0004	.0005	.0006
.2	.0006	.0007	.0008	.0008	.0009	.0010	.0011	.0011	.0012	.0013
.3	.0014	.0015	.0016	.0017	.0018	.0019	.0020	.0021	.0022	.0023
.4	.0025	.0026	.0027	.0029	.0030	.0031	.0033	.0034	.0036	.0037
.5	.0039	.0040	.0042	.0044	.0045	.0047	.0049	.0051	.0052	.0054
.6	.0056	.0058	.0060	.0062	.0064	.0066	.0068	.0070	.0072	.0074
.7	.0076	.0078	.0081	.0083	.0085	.0087	.0090	.0092	.0095	.0097
.8	.0099	.0102	.0105	.0107	.0110	.0112	.0115	.0118	.0120	.0123
.9	.0126	.0129	.0132	.0134	.0137	.0140	.0143	.0146	.0149	.0152
1.0	0.0155	0.0159	0.0162	0.0165	0.0168	0.0171	0.0175	0.0178	0.0181	0.0185
.1	.0188	.0192	.0195	.0199	.0202	.0206	.0209	.0213	.0216	.0220
.2	.0224	.0228	.0231	.0235	.0239	.0243	.0247	.0251	.0255	.0259
.3	.0263	.0267	.0271	.0275	.0279	.0283	.0288	.0292	.0296	.0300
.4	.0305	.0309	.0313	.0318	.0322	.0327	.0331	.0336	.0341	.0345
.5	.0350	.0354	.0359	.0364	.0369	.0374	.0378	.0383	.0388	.0393
.6	.0398	.0403	.0408	.0413	.0418	.0423	.0428	.0434	.0439	.0444
.7	.0449	.0455	.0460	.0465	.0471	.0476	.0482	.0487	.0493	.0498
.8	.0504	.0509	.0515	.0521	.0526	.0532	.0538	.0544	.0549	.0555
.9	.0561	.0567	.0573	.0579	.0585	.0591	.0597	.0603	.0609	.0616
2.0	0.0622	0.0628	0.0634	0.0641	0.0647	0.0653	0.0660	0.0666	0.0673	0.0679
.1	.0686	.0692	.0699	.0705	.0712	.0719	.0725	.0732	.0739	.0746
.2	.0752	.0759	.0766	.0773	.0780	.0787	.0794	.0801	.0808	.0815
.3	.0822	.0830	.0837	.0844	.0851	.0859	.0866	.0873	.0881	.0888
.4	.0895	.0903	.0910	.0918	.0926	.0933	.0941	.0948	.0956	.0964
.5	.0972	.0979	.0987	.0995	.1003	.1011	.1019	.1027	.1035	.1043
.6	.1051	.1059	.1067	.1075	.1084	.1092	.1100	.1108	.1117	.1125
.7	.1133	.1142	.1150	.1159	.1167	.1176	.1184	.1193	.1201	.1210
.8	.1219	.1228	.1236	.1245	.1254	.1263	.1272	.1281	.1289	.1298
.9	.1307	.1316	.1326	.1335	.1344	.1353	.1362	.1371	.1381	.1390
3.0	0.1399	0.1409	0.1418	0.1427	0.1437	0.1446	0.1456	0.1465	0.1475	0.1484
.1	.1494	.1504	.1513	.1523	.1533	.1543	.1552	.1562	.1572	.1582
.2	.1592	.1602	.1612	.1622	.1632	.1642	.1652	.1662	.1673	.1683
.3	.1693	.1703	.1714	.1724	.1734	.1745	.1755	.1766	.1776	.1787
.4	.1797	.1808	.1818	.1829	.1840	.1850	.1861	.1872	.1883	.1894
.5	.1904	.1915	.1926	.1937	.1948	.1959	.1970	.1981	.1992	.2004
.6	.2015	.2026	.2037	.2049	.2060	.2071	.2083	.2094	.2105	.2117
.7	.2128	.2140	.2151	.2163	.2175	.2186	.2198	.2210	.2221	.2233
.8	.2245	.2257	.2269	.2280	.2292	.2304	.2316	.2328	.2340	.2352
.9	.2365	.2377	.2389	.2401	.2413	.2426	.2438	.2450	.2463	.2475
4.0	0.2487	0.2500	0.2512	0.2525	0.2537	0.2550	0.2563	0.2575	0.2588	0.2601
.1	.2613	.2626	.2639	.2652	.2665	.2677	.2690	.2703	.2716	.2729
.2	.2742	.2755	.2769	.2782	.2795	.2808	.2821	.2835	.2848	.2861
.3	.2875	.2888	.2901	.2915	.2928	.2942	.2955	.2969	.2982	.2996
.4	.3010	.3023	.3037	.3051	.3065	.3079	.3092	.3106	.3120	.3134
.5	.3148	.3162	.3176	.3190	.3204	.3218	.3233	.3247	.3261	.3275
.6	.3290	.3304	.3318	.3333	.3347	.3362	.3376	.3390	.3405	.3420
.7	.3434	.3449	.3463	.3478	.3493	.3508	.3522	.3537	.3552	.3567
.8	.3582	.3597	.3612	.3627	.3642	.3657	.3672	.3687	.3702	.3717
.9	.3733	.3748	.3763	.3779	.3794	.3809	.3825	.3840	.3856	.3871

is value will suffice in ordinary corrections for velocity of ›ach for localities in the United States.

Velocity of approach correction.

is, and as used in portions of this paper (approximate)	$H=D+h$
· and Stearns, contracted weir	$H=D+1.5h$
lton Smith, suppressed weir	$H=D+1\frac{1}{3}h$
lton Smith, contracted weir	$H=D+1.4h$

LE 2.—PERCENTAGE INCREASE IN DISCHARGE BY VARIOUS RATES OF VELOCITY OF APPROACH.

is table has been calculated from the Francis correction formula,

$$H^{\frac{3}{2}}=(D+h)^{\frac{3}{2}}-h^{\frac{3}{2}}.$$

e percentage increase in discharge over that at the same meas- head with no velocity of approach is

$$\text{Percentage}=100\frac{H^{\frac{3}{2}}-D^{\frac{3}{2}}}{D^{\frac{3}{2}}}=K \quad . \quad . \quad . \quad . \quad (113)$$

TABLE 2.—*Percentage increase in discharge over weirs for various rates of mean velocity of approach.*

D=measured head in feet; H=head corrected for velocity of approach; v=mean velocity of approach, feet per second; $h=\frac{v^2}{2g}$; $H=\left[(D+h)^{\frac{3}{2}}-h^{\frac{3}{2}}\right]^{\frac{2}{3}}$.

v	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2
h	0.0025	0.0039	0.0056	0.0076	0.0099	0.0126	0.0155	0.0188	0.0224	0.0263	0.0305	0.0350	0.0398	0.0449	0.0504	0.0561	0.0622	0.0686	0.0752
$h^{\frac{3}{2}}$	0.0002	0.0003	0.0005	0.0007	0.0010	0.0014	0.0019	0.0025	0.0033	0.0041	0.0051	0.0064	0.0079	0.0095	0.0111	0.0132	0.0154	0.0179	0.0206
D	Percentage increase in discharge $=100\left[1-\frac{H^{\frac{3}{2}}}{D^{\frac{3}{2}}}\right]$																		
0.2	1.36	2.65	3.72	5.02	6.44	8.16	9.77	12.19	14.13	16.34	18.62	20.80	22.51	25.39	27.74	30.78	33.55	36.30	39.06
.4	.68	1.34	1.90	2.58	3.33	4.20	5.11	6.16	7.20	8.39	9.62	10.86	12.16	13.54	14.94	16.53	18.11	19.72	21.34
.6	.42	.90	1.29	1.74	2.22	2.86	3.44	4.14	4.88	5.69	6.56	7.49	8.40	9.33	10.42	11.49	12.57	13.72	14.86
.8	.40	.62	.92	1.26	1.62	2.11	2.66	3.12	3.70	4.33	4.98	5.67	6.45	7.14	7.97	8.88	9.66	10.56	14.76
1.0	.36	.56	.79	1.07	1.40	1.76	2.15	2.59	3.05	3.56	4.10	4.66	5.24	5.86	6.54	7.21	7.93	8.68	9.43
1.5	.24	.37	.53	.72	.94	1.19	1.45	1.75	2.07	2.43	2.79	3.22	3.50	4.01	4.48	4.94	5.45	5.96	6.49
2.0	.19	.29	.41	.59	.72	.91	1.11	1.34	1.58	1.84	2.13	2.42	2.72	3.06	3.42	3.78	4.17	4.57	4.98
2.5	.18	.22	.31	.43	.56	.71	.88	1.06	1.25	1.47	1.70	1.94	2.19	2.45	2.75	3.04	3.36	3.68	3.95
3.0	.12	.19	.27	.36	.47	.60	.74	.89	1.06	1.24	1.43	1.63	1.84	2.07	2.31	2.56	2.83	3.10	3.38
3.5	.10	.16	.23	.31	.40	.47	.63	.76	.90	1.06	1.23	1.40	1.58	1.78	1.99	2.21	2.48	2.67	2.93
4.0	.09	.14	.20	.27	.35	.45	.55	.67	.80	.93	1.08	1.23	1.39	1.57	1.75	1.94	2.14	2.36	2.57
4.5	.08	.12	.18	.24	.31	.40	.49	.60	.71	.83	.96	1.10	1.24	1.40	1.56	1.73	1.92	2.10	2.30
5.0	.07	.11	.16	.22	.27	.35	.44	.54	.65	.75	.83	.98	1.12	1.26	1.42	1.57	1.64	1.90	2.07
5.5	.06	.10	.14	.20	.27	.33	.40	.49	.58	.68	.78	.90	1.00	1.15	1.28	1.43	1.57	1.73	1.90
6.0	.06	.09	.13	.17	.23	.30	.37	.45	.53	.63	.72	.84	.94	1.05	1.18	1.31	1.45	1.59	1.74
6.5	.06	.08	.12	.17	.22	.28	.34	.41	.49	.58	.67	.76	.87	.98	1.12	1.21	1.34	1.47	1.61
7.0	.05	.08	.11	.15	.20	.26	.32	.39	.46	.54	.63	.72	.80	.91	1.02	1.13	1.25	1.37	1.50
7.5	.04	.07	.10	.14	.18	.24	.29	.36	.43	.50	.58	.66	.75	.84	.95	1.05	1.17	1.28	1.40
8.0	.04	.07	.10	.14	.18	.23	.28	.34	.40	.47	.55	.63	.71	.80	.90	.99	1.10	1.21	1.32
8.5	.04	.06	.09	.13	.16	.21	.26	.31	.38	.44	.51	.59	.67	.75	.84	.93	1.03	1.13	1.24
9.0	.04	.06	.09	.12	.16	.20	.25	.30	.36	.42	.48	.55	.63	.71	.80	.88	.98	1.07	1.17
9.5	.04	.06	.08	.11	.15	.19	.23	.28	.34	.40	.46	.53	.60	.67	.75	.84	.93	1.02	1.11
10.0	.04	.05	.08	.10	.14	.19	.23	.27	.31	.37	.44	.50	.57	.64	.71	.79	.84	.90	1.00

v	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0
h	0.0822	0.0895	0.0972	0.1051	0.1133	0.1219	0.1307	0.1399	0.1494	0.1592	0.1693	0.1797	0.1904	0.2015	0.2128	0.2128	0.2365	0.2487
$h^{\frac{3}{2}}$	0.0235	0.0268	0.0303	0.0340	0.0381	0.0426	0.0472	0.0524	0.0576	0.0634	0.0696	0.0761	0.0830	0.0904	0.0982	0.1064	0.1150	0.1242
D	Percentage increase in discharge $=100\left[1-\frac{H^{\frac{3}{2}}}{D^{\frac{3}{2}}}\right]$																	
0.2	42.03	44.91	48.00	51.14	54.22	57.34	60.64	63.68	67.34	70.65	73.96	75.58	80.80	84.28	87.66	90.35	93.94	97.27
.4	23.06	24.77	26.59	28.45	30.29	32.19	34.15	36.09	38.15	40.22	42.27	44.37	46.50	48.66	50.79	53.07	55.26	57.39
.6	16.12	17.64	18.68	20.02	37.16	22.80	24.17	25.60	27.12	28.62	30.14	31.75	33.26	34.87	36.47	38.12	39.86	41.49
.8	12.44	13.42	14.46	15.51	16.58	17.77	18.89	19.95	21.16	22.26	23.56	24.80	26.06	27.36	28.64	29.97	31.28	32.73
1.0	10.23	11.04	11.90	12.77	13.66	14.57	15.51	16.46	17.47	18.47	19.48	20.52	21.58	22.66	23.74	24.86	26.00	27.11
1.5	7.06	7.65	8.28	8.84	9.47	10.03	10.78	11.46	12.12	12.88	13.62	14.36	15.12	15.90	16.67	17.48	18.30	18.84
2.0	5.44	5.85	6.32	6.79	7.28	7.78	8.30	8.83	9.39	9.93	10.51	11.10	11.69	12.27	12.92	13.55	14.18	14.83
2.5	4.36	4.73	5.11	5.50	5.90	6.32	6.74	7.17	7.63	8.09	8.56	9.04	9.53	10.04	10.54	11.07	11.60	12.14
3.0	3.68	3.99	4.31	4.64	4.98	5.33	5.70	6.07	6.45	6.84	7.24	7.78	8.00	8.50	8.93	9.38	9.84	10.29
3.5	3.18	3.44	3.73	4.01	4.31	4.61	4.93	5.25	6.04	5.93	6.27	6.63	7.00	7.37	7.75	8.14	8.54	8.86
4.0	2.80	3.04	3.28	3.54	3.80	4.07	4.35	4.63	4.93	5.23	5.54	5.86	6.24	6.52	6.85	7.20	7.56	7.91
4.5	2.50	2.71	2.93	3.16	3.40	3.64	3.89	4.14	4.41	4.68	4.96	5.24	5.5	5.84	6.14	6.45	6.7	7.11
5.0	2.26	2.46	2.66	2.87	3.09	3.30	3.53	3.76	4.00	4.25	4.50	4.75	5.0	5.30	5.57	5.86	6.15	6.44
5.5	2.10	2.24	2.42	2.61	2.80	3.01	3.21	3.43	3.63	3.88	4.11	4.34	4.59	4.84	5.09	5.35	5.63	5.88
6.0	1.90	2.06	2.22	2.40	2.58	2.77	2.96	3.09	3.36	3.57	3.78	4.00	4.2	4.46	4.69	4.93	5.1	5.40
6.5	1.75	1.90	2.06	2.22	2.39	2.56	2.74	2.94	3.17	3.31	3.57	3.71	3.9	4.13	4.35	4.52	4.8	5.01
7.0	1.63	1.78	1.92	2.07	2.23	2.39	2.55	2.67	2.96	3.09	3.27	3.46	3.6	3.86	4.06	4.15	4.4	4.68
7.5	1.53	1.66	1.80	1.94	2.13	2.22	2.39	2.55	2.73	2.88	3.06	3.24	3.4	3.61	3.80	4.00	4.2	4.41
8.0	1.44	1.56	1.69	1.82	1.96	2.10	2.25	2.40	2.56	2.72	2.88	3.04	3.2	3.40	3.58	3.76	3.9	4.13
8.5	1.35	1.47	1.59	1.72	1.85	1.98	2.12	2.26	2.41	2.56	2.72	2.88	3.0	3.20	3.38	3.55	3.7	3.89
9.0	1.28	1.39	1.51	1.62	1.78	1.87	2.0	2.14	2.28	2.43	2.57	2.72	2.9	3.04	3.20	3.36	3.5	3.69
9.5	1.22	1.32	1.43	1.54	1.66	1.78	1.90	2.03	2.17	2.30	2.44	2.59	2.7	2.88	3.04	3.20	3.3	3.51
10.0	1.15	1.25	1.36	1.47	1.57	1.68	1.80	1.94	2.05	2.19	2.32	2.47	2.6	2.74	2.89	3.04	3.2	3.36

To use this table the discharge corresponding to the measured hea D may be taken directly from Table 3 or 4 and the quantity so obtaine increased by the percentage indicated in Table 2. This table is esp cially useful where the velocity of approach is measured directly. I the velocity of approach is determined from the approximate discharg by the formula $v=\frac{Q}{A}$, successive approximate corrections may b required.

Table 2 shows directly the relative error introduced by various veloci- ties of approach. The large error introduced by moderate velocities with low heads and the comparatively small error resulting from higher velocities under great heads are conspicuous.

TABLES 3 AND 4.—DISCHARGE OVER A THIN-EDGED WEIR BY THE FRANCIS FORMULA.

These tables give the discharge in cubic feet per second, for a crest length of 1 foot, without contractions, computed by the formula

$$Q=3.33LH^{\frac{3}{2}}.$$

TABLE 3.—*Discharge over a thin-edged weir per foot of crest.*

Head H, feet.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
0.00	0.0000	0.0001	0.0003	0.0005	0.0008	0.0012	0.0015	0.0020	0.0024	0.0028
.01	.0033	.0038	.0044	.0049	.0055	.0061	.0067	.0074	.0080	.0087
.02	.0094	.0101	.0109	.0116	.0124	.0132	.0140	.0148	.0156	.0164
.03	.0173	.0182	.0191	.0200	.0209	.0218	.0227	.0237	.0247	.0256
.04	.0266	.0276	.0287	.0297	.0307	.0318	.0329	.0339	.0350	.0361
.05	.0372	.0384	.0395	.0406	.0418	.0430	.0441	.0453	.0465	.0477
.06	.0489	.0502	.0514	.0527	.0539	.0552	.0565	.0578	.0590	.0604
.07	.0617	.0630	.0643	.0657	.0670	.0684	.0698	.0712	.0725	.0739
.08	.0753	.0768	.0782	.0796	.0811	.0825	.0840	.0855	.0869	.0884
.09	.0899	.0914	.0929	.0944	.0960	.0975	.0990	.1006	.1022	.1037
0.10	0.1053	0.1069	0.1085	0.1101	0.1117	0.1133	0.1149	0.1166	0.1182	0.1198
.11	.1215	.1231	.1248	.1265	.1282	.1299	.1316	.1333	.1350	.1367
.12	.1384	.1402	.1419	.1436	.1454	.1472	.1489	.1507	.1525	.1543
.13	.1561	.1579	.1597	.1615	.1633	.1652	.1670	.1689	.1707	.1726
.14	.1744	.1763	.1782	.1801	.1820	.1839	.1858	.1877	.1896	.1915
.15	.1935	.1954	.1973	.1993	.2012	.2032	.2052	.2072	.2091	.2111
.16	.2131	.2151	.2171	.2191	.2212	.2232	.2252	.2273	.2293	.2314
.17	.2334	.2355	.2375	.2396	.2417	.2438	.2459	.2480	.2501	.2522
.18	.2543	.2564	.2586	.2607	.2628	.2650	.2671	.2693	.2714	.2736
.19	.2758	.2780	.2802	.2823	.2845	.2867	.2890	.2912	.2934	.2956
0.20	0.2978	0.3001	0.3023	0.3046	0.3068	0.3091	0.3113	0.3136	0.3159	0.3182
.21	.3205	.3228	.3250	.3274	.3297	.3320	.3343	.3366	.3389	.3413
.22	.3436	.3460	.3483	.3507	.3530	.3554	.3578	.3601	.3625	.3649
.23	.3673	.3697	.3721	.3745	.3769	.3794	.3818	.3842	.3866	.3891
.24	.3915	.3940	.3964	.3989	.4014	.4038	.4063	.4088	.4113	.4138
.25	.4162	.4187	.4213	.4238	.4263	.4288	.4313	.4339	.4364	.4389
.26	.4415	.4440	.4466	.4491	.4517	.4543	.4568	.4594	.4620	.4646
.27	.4672	.4698	.4724	.4750	.4776	.4802	.4828	.4855	.4881	.4907
.28	.4934	.4960	.4987	.5013	.5040	.5067	.5093	.5120	.5147	.5174
.29	.5200	.5227	.5254	.5281	.5308	.5336	.5363	.5390	.5417	.5444

TABLE 3.—*Discharge over a thin-edged weir per foot of crest*—Continued.

ead *H*, feet.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
0.30	0.5472	0.5499	0.5527	0.5554	0.5582	0.5609	0.5637	0.5664	0.5692	0.5720
.31	.5748	.5775	.5803	.5831	.5859	.5887	.5915	.5943	.5972	.6000
.32	.6028	.6056	.6085	.6113	.6141	.6170	.6198	.6227	.6255	.6284
.33	.6313	.6341	.6370	.6399	.6428	.6457	.6486	.6515	.6544	.6573
.34	.6602	.6631	.6660	.6689	.6719	.6748	.6777	.6807	.6836	.6866
.35	.6895	.6925	.6954	.6984	.7014	.7043	.7073	.7103	.7133	.7163
.36	.7193	.7223	.7253	.7283	.7313	.7343	.7373	.7404	.7434	.7464
.37	.7495	.7525	.7555	.7586	.7616	.7647	.7678	.7708	.7739	.7770
.38	.7800	.7831	.7862	.7893	.7924	.7955	.7986	.8017	.8048	.8079
.39	.8110	.8142	.8173	.8204	.8235	.8267	.8298	.8330	.8361	.8393
0.40	0.8424	0.8456	0.8488	0.8519	0.8551	0.8583	0.8615	0.8646	0.8678	0.8710
.41	.8742	.8774	.8806	.8838	.8870	.8903	.8935	.8967	.8999	.9032
.42	.9064	.9096	.9129	.9161	.9194	.9226	.9259	.9292	.9324	.9357
.43	.9390	.9422	.9455	.9488	.9521	.9554	.9587	.9620	.9653	.9686
.44	.9719	.9752	.9785	.9819	.9852	.9885	.9919	.9952	.9985	1.0019
.45	1.0052	1.0086	1.0119	1.0153	1.0187	1.0220	1.0254	1.0288	1.0321	1.0355
.46	1.0389	1.0423	1.0457	1.0491	1.0525	1.0559	1.0593	1.0627	1.0661	1.0696
.47	1.0730	1.0764	1.0798	1.0833	1.0867	1.0901	1.0936	1.0970	1.1005	1.1039
.48	1.1074	1.1109	1.1143	1.1178	1.1213	1.1248	1.1282	1.1317	1.1352	1.1387
.49	1.1422	1.1457	1.1492	1.1527	1.1562	1.1597	1.1632	1.1668	1.1703	1.1738
0.50	1.1773	1.1809	1.1844	1.1879	1.1915	1.1950	1.1986	1.2021	1.2057	1.2093
.51	1.2128	1.2164	1.2200	1.2235	1.2271	1.2307	1.2343	1.2379	1.2415	1.2451
.52	1.2487	1.2523	1.2559	1.2595	1.2631	1.2667	1.2703	1.2740	1.2776	1.2812
.53	1.2849	1.2885	1.2921	1.2958	1.2994	1.3031	1.3067	1.3104	1.3141	1.3177
.54	1.3214	1.3251	1.3287	1.3324	1.3361	1.3398	1.3435	1.3472	1.3509	1.3546
.55	1.3583	1.3620	1.3657	1.3694	1.3731	1.3768	1.3806	1.3843	1.3880	1.3918
.56	1.3955	1.3992	1.4030	1.4067	1.4105	1.4142	1.4180	1.4217	1.4255	1.4293
.57	1.4330	1.4368	1.4406	1.4444	1.4481	1.4519	1.4557	1.4595	1.4633	1.4671
.58	1.4709	1.4747	1.4785	1.4823	1.4862	1.4900	1.4938	1.4976	1.5014	1.5053
.59	1.5091	1.5130	1.5168	1.5206	1.5245	1.5283	1.5322	1.5361	1.5399	1.5438
0.60	1.5476	1.5515	1.5554	1.5593	1.5631	1.5670	1.5709	1.5748	1.5787	1.5826
.61	1.5865	1.5904	1.5943	1.5982	1.6021	1.6060	1.6100	1.6139	1.6178	1.6217
.62	1.6257	1.6296	1.6335	1.6375	1.6414	1.6454	1.6493	1.6533	1.6572	1.6612
.63	1.6652	1.6691	1.6731	1.6771	1.6810	1.6850	1.6890	1.6930	1.6970	1.7010
.64	1.7050	1.7090	1.7130	1.7170	1.7210	1.7250	1.7290	1.7330	1.7370	1.7410
.65	1.7451	1.7491	1.7531	1.7572	1.7612	1.7652	1.7693	1.7733	1.7774	1.7814
.66	1.7855	1.7896	1.7936	1.7977	1.8018	1.8058	1.8099	1.8140	1.8181	1.8221
.67	1.8262	1.8303	1.8344	1.8385	1.8426	1.8467	1.8508	1.8549	1.8590	1.8632
.68	1.8673	1.8714	1.8755	1.8796	1.8838	1.8879	1.8920	1.8962	1.9003	1.9045
.69	1.9086	1.9128	1.9169	1.9211	1.9252	1.9294	1.9336	1.9377	1.9419	1.9461
0.70	1.9503	1.9544	1.9586	1.9628	1.9670	1.9712	1.9754	1.9796	1.9838	1.9880
.71	1.9922	1.9964	2.0006	2.0048	2.0091	2.0133	2.0175	2.0217	2.0260	2.0302
.72	2.0344	2.0387	2.0429	2.0472	2.0514	2.0557	2.0599	2.0642	2.0684	2.0727
.73	2.0770	2.0812	2.0855	2.0898	2.0941	2.0983	2.1026	2.1069	2.1112	2.1155
.74	2.1198	2.1241	2.1284	2.1327	2.1370	2.1413	2.1456	2.1499	2.1543	2.1586
.75	2.1629	2.1672	2.1716	2.1759	2.1802	2.1846	2.1889	2.1932	2.1976	2.2019
.76	2.2063	2.2107	2.2150	2.2194	2.2237	2.2281	2.2325	2.2369	2.2412	2.2456
.77	2.2500	2.2544	2.2588	2.2632	2.2675	2.2719	2.2763	2.2807	2.2851	2.2896
.78	2.2940	2.2984	2.3028	2.3072	2.3116	2.3161	2.3205	2.3249	2.3293	2.3338
.79	2.3382	2.3427	2.3471	2.3515	2.3560	2.3604	2.3649	2.3694	2.3738	2.3783

TABLE 3.—*Discharge over a thin-edged weir per foot of crest*—Continued.

Head *H*, feet.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
0.80	2.3828	2.3872	2.3917	2.3962	2.4006	2.4051	2.4096	2.4141	2.4186	2.4231
.81	2.4276	2.4321	2.4366	2.4411	2.4456	2.4501	2.4546	2.4591	2.4636	2.4681
.82	2.4727	2.4772	2.4817	2.4862	2.4908	2.4953	2.4999	2.5044	2.5089	2.5135
.83	2.5180	2.5226	2.5271	2.5317	2.5363	2.5408	2.5454	2.5500	2.5545	2.5591
.84	2.5637	2.5683	2.5728	2.5774	2.5820	2.5866	2.5912	2.5958	2.6004	2.6050
.85	2.6096	2.6142	2.6188	2.6234	2.6280	2.6327	2.6373	2.6419	2.6465	2.6511
.86	2.6558	2.6604	2.6650	2.6697	2.6743	2.6790	2.6836	2.6883	2.6929	2.6976
.87	2.7022	2.7069	2.7116	2.7162	2.7209	2.7256	2.7302	2.7349	2.7396	2.7443
.88	2.7490	2.7536	2.7583	2.7630	2.7677	2.7724	2.7771	2.7818	2.7865	2.7912
.89	2.7959	2.8007	2.8054	2.8101	2.8148	2.8195	2.8243	2.8290	2.8337	2.8385
0.90	2.8432	2.8479	2.8527	2.8574	2.8622	2.8669	2.8717	2.8764	2.8812	2.8860
.91	2.8907	2.8955	2.9003	2.9050	2.9098	2.9146	2.9194	2.9241	2.9289	2.9337
.92	2.9385	2.9433	2.9481	2.9529	2.9577	2.9625	2.9673	2.9721	2.9769	2.9817
.93	2.9865	2.9914	2.9962	3.0010	3.0058	3.0107	3.0155	3.0203	3.0252	3.0300
.94	3.0348	3.0397	3.0445	3.0494	3.0542	3.0591	3.0639	3.0688	3.0737	3.0785
.95	3.0834	3.0883	3.0931	3.0980	3.1029	3.1078	3.1127	3.1175	3.1224	3.1273
.96	3.1322	3.1371	3.1420	3.1469	3.1518	3.1567	3.1616	3.1665	3.1714	3.1764
.97	3.1813	3.1862	3.1911	3.1960	3.2010	3.2059	3.2108	3.2158	3.2207	3.2257
.98	3.2306	3.2355	3.2405	3.2454	3.2504	3.2554	3.2603	3.2653	3.2702	3.2752
.99	3.2802	3.2851	3.2901	3.2951	3.3001	3.3051	3.3100	3.3150	3.3200	3.3250
1.00	3.3300	3.3350	3.3400	3.3450	3.3500	3.3550	3.3600	3.3650	3.3700	3.3751
.01	3.3801	3.3851	3.3901	3.3951	3.4002	3.4052	3.4102	3.4153	3.4203	3.4254
.02	3.4304	3.4354	3.4405	3.4455	3.4506	3.4557	3.4607	3.4658	3.4708	3.4759
.03	3.4810	3.4860	3.4911	3.4962	3.5013	3.5063	3.5114	3.5165	3.5216	3.5267
.04	3.5318	3.5369	3.5420	3.5471	3.5522	3.5573	3.5624	3.5675	3.5726	3.5777
.05	3.5828	3.5880	3.5931	3.5982	3.6033	3.6085	3.6136	3.6187	3.6239	3.6290
.06	3.6342	3.6393	3.6444	3.6496	3.6547	3.6599	3.6651	3.6702	3.6754	3.6805
.07	3.6857	3.6909	3.6960	3.7012	3.7064	3.7116	3.7167	3.7219	3.7271	3.7323
.08	3.7375	3.7427	3.7479	3.7531	3.7583	3.7635	3.7687	3.7739	3.7791	3.7843
.09	3.7895	3.7947	3.8000	3.8052	3.8104	3.8156	3.8209	3.8261	3.8313	3.8365
1.10	3.8418	3.8470	3.8523	3.8575	3.8628	3.8680	3.8733	3.8785	3.8838	3.8890
.11	3.8943	3.8996	3.9048	3.9101	3.9154	3.9206	3.9259	3.9312	3.9365	3.9418
.12	3.9470	3.9523	3.9576	3.9629	3.9682	3.9735	3.9788	3.9841	3.9894	3.9947
.13	4.0000	4.0053	4.0106	4.0160	4.0213	4.0266	4.0319	4.0372	4.0426	4.0479
.14	4.0532	4.0586	4.0639	4.0692	4.0746	4.0799	4.0853	4.0906	4.0960	4.1013
.15	4.1067	4.1120	4.1174	4.1228	4.1281	4.1335	4.1389	4.1442	4.1496	4.1550
.16	4.1604	4.1657	4.1711	4.1765	4.1819	4.1873	4.1927	4.1981	4.2035	4.2089
.17	4.2143	4.2197	4.2251	4.2305	4.2359	4.2413	4.2467	4.2522	4.2576	4.2630
.18	4.2684	4.2738	4.2793	4.2847	4.2901	4.2956	4.3010	4.3065	4.3119	4.3173
.19	4.3228	4.3282	4.3337	4.3392	4.3446	4.3501	4.3555	4.3610	4.3665	4.3719
1.20	4.3774	4.3829	4.3883	4.3938	4.3993	4.4048	4.4103	4.4158	4.4212	4.4267
.21	4.4322	4.4377	4.4432	4.4487	4.4542	4.4597	4.4652	4.4707	4.4763	4.4818
.22	4.4873	4.4928	4.4983	4.5038	4.5094	4.5149	4.5204	4.5260	4.5315	4.5370
.23	4.5426	4.5481	4.5537	4.5592	4.5647	4.5703	4.5759	4.5814	4.5870	4.5925
.24	4.5981	4.6036	4.6092	4.6148	4.6203	4.6259	4.6315	4.6371	4.6427	4.6482
.25	4.6538	4.6594	4.6650	4.6706	4.6762	4.6818	4.6874	4.6930	4.6986	4.7042
.26	4.7098	4.7154	4.7210	4.7266	4.7322	4.7378	4.7435	4.7491	4.7547	4.7603
.27	4.7660	4.7716	4.7772	4.7829	4.7885	4.7941	4.7998	4.8054	4.8111	4.8167
.28	4.8224	4.8280	4.8337	4.8393	4.8450	4.8506	4.8563	4.8620	4.8676	4.8733
.29	4.8790	4.8847	4.8903	4.8960	4.9017	4.9074	4.9131	4.9187	4.9244	4.9301

TABLE 3.—*Discharge over a thin-edged weir per foot of crest*—Continued.

ead *H*, feet.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
1.30	4.9358	4.9415	4.9472	4.9529	4.9586	4.9643	4.9700	4.9757	4.9814	4.9872
.31	4.9929	4.9986	5.0043	5.0100	5.0158	5.0215	5.0272	5.0330	5.0387	5.0444
.32	5.0502	5.0559	5.0616	5.0674	5.0731	5.0789	5.0846	5.0904	5.0961	5.1019
.33	5.1077	5.1134	5.1192	5.1249	5.1307	5.1365	5.1423	5.1480	5.1538	5.1596
.34	5.1654	5.1712	5.1769	5.1827	5.1885	5.1943	5.2001	5.0259	5.2117	5.2175
.35	5.2233	5.2291	5.2349	5.2407	5.2465	5.2523	5.2582	5.2640	5.2698	5.2756
.36	5.2814	5.2873	5.2931	5.2989	5.3048	5.3106	5.3164	5.3223	5.3281	5.3340
.37	5.3398	5.3456	5.3515	5.3573	5.3632	5.3691	5.3749	5.3808	5.3866	5.3925
.38	5.3984	5.4142	5.4101	5.4160	5.4219	5.4277	5.4336	5.4395	5.4454	5.4513
.39	5.4572	5.4630	5.4689	5.4748	5.4807	5.4866	5.4925	5.4984	5.5043	5.5102
1.40	5.5162	5.5221	5.5280	5.5339	5.5398	5.5457	5.5516	5.5576	5.5635	5.5694
.41	5.5754	5.5813	5.5872	5.5932	5.5991	5.6050	5.6110	5.6169	5.6229	5.6288
.42	5.6348	5.6407	5.6467	5.6526	5.6586	5.6646	5.6705	5.6765	5.6825	5.6884
.43	5.6944	5.7004	5.7064	5.7123	5.7183	5.7243	5.7303	5.7363	5.7423	5.7482
.44	5.7542	5.7602	5.7662	5.7722	5.7782	5.7842	5.7902	5.7962	5.8023	5.8083
.45	5.8143	5.8203	5.8263	5.8323	5.8384	5.8444	5.8504	5.8564	5.8625	5.8685
.46	5.8745	5.8806	5.8866	5.8926	5.8987	5.9047	5.9108	5.9168	5.9229	5.9289
.47	5.9350	5.9410	5.9471	5.9532	5.9592	5.9653	5.9714	5.9774	5.9835	5.9896
.48	5.9957	6.0017	6.0078	6.0139	6.0200	6.0261	6.0322	6.0382	6.0443	6.0504
.49	6.0565	6.0626	6.0687	6.0748	6.0809	6.0870	6.0931	6.0993	6.1054	6.1115
1.50	6.1176	6.1237	6.1298	6.1360	6.1421	6.1482	6.1543	6.1605	6.1666	6.1727
.51	6.1789	6.1850	6.1912	6.1973	6.2034	6.2096	6.2157	6.2219	6.2280	6.2342
.52	6.2404	6.2465	6.2527	6.2588	6.2650	6.2712	6.2773	6.2835	6.2897	6.2959
.53	6.3020	6.3082	6.3144	6.3206	6.3268	6.3330	6.3391	6.3453	6.3515	6.3577
.54	6.3639	6.3701	6.3763	6.3825	6.3887	6.3949	6.4012	6.4074	6.4136	6.4198
.55	6.4260	6.4322	6.4385	6.4447	6.4509	6.4571	6.4634	6.4696	6.4758	6.4821
.56	6.4883	6.4945	6.5008	6.5070	6.5133	6.5195	6.5258	6.5320	6.5383	6.5445
.57	6.5508	6.5570	6.5633	6.5696	6.5758	6.5821	6.5884	6.5946	6.6009	6.6072
.58	6.6135	6.6198	6.6260	6.6323	6.6386	6.6449	6.6512	6.6575	6.6638	6.6701
.59	6.6764	6.6827	6.6890	6.6953	6.7016	6.7079	6.7142	6.7205	6.7268	6.7331
1.60	6.7394	6.7458	6.7521	6.7584	6.7647	6.7711	6.7774	6.7837	6.7901	6.7964
.61	6.8027	6.8091	6.8154	6.8217	6.8281	6.8344	6.8408	6.8471	6.8535	6.8598
.62	6.8662	6.8726	6.8789	6.8853	6.8916	6.8980	6.9044	6.9108	6.9171	6.9235
.63	6.9299	6.9363	6.9426	6.9490	6.9554	6.9618	6.9682	6.9746	6.9810	6.9874
.64	6.9937	7.0001	7.0065	7.0129	7.0193	7.0258	7.0322	7.0386	7.0450	7.0514
.65	7.0578	7.0642	7.0706	7.0771	7.0835	7.0899	7.0963	7.1028	7.1092	7.1156
.66	7.1221	7.1285	7.1349	7.1414	7.1478	7.1543	7.1607	7.1672	7.1736	7.1801
.67	7.1865	7.1930	7.1994	7.2059	7.2124	7.2188	7.2253	7.2318	7.2382	7.2447
.68	7.2512	7.2576	7.2641	7.2706	7.2771	7.2836	7.2901	7.2965	7.3030	7.3095
.69	7.3160	7.3225	7.3290	7.3355	7.3420	7.3485	7.3550	7.3615	7.3680	7.3745
1.70	7.3810	7.3876	7.3941	7.4006	7.4071	7.4136	7.4201	7.4267	7.4332	7.4397
.71	7.4463	7.4528	7.4593	7.4659	7.4724	7.4789	7.4855	7.4920	7.4986	7.5051
.72	7.5117	7.5182	7.5248	7.5313	7.5379	7.5445	7.5510	7.5576	7.5641	7.5707
.73	7.5773	7.5839	7.5904	7.5970	7.6036	7.6102	7.6167	7.6233	7.6299	7.6365
.74	7.6431	7.6497	7.6563	7.6628	7.6694	7.6760	7.6826	7.6892	7.6958	7.7024
.75	7.7091	7.7157	7.7223	7.7289	7.7355	7.7421	7.7487	7.7554	7.7620	7.7686
.76	7.7752	7.7819	7.7885	7.7951	7.8018	7.8084	7.8150	7.8217	7.8283	7.8349
.77	7.8416	7.8482	7.8549	7.8615	7.8682	7.8748	7.8815	7.8882	7.8948	7.9015
.78	7.9081	7.9148	7.9215	7.9281	7.9348	7.9415	7.9482	7.9548	7.9615	7.9682
.79	7.9749	7.9816	7.9882	7.9949	8.0016	8.0083	8.0150	8.0217	8.0284	8.0351

TABLE 3.—*Discharge over a thin-edged weir per foot of crest*—Continued.

Head *H*, feet.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
1.80	8.0418	8.0485	8.0552	8.0619	8.0686	8.0753	8.0820	8.0888	8.0955	8.1022
.81	8.1089	8.1156	8.1223	8.1291	8.1358	8.1425	8.1493	8.1560	8.1627	8.1695
.82	8.1762	8.1829	8.1897	8.1964	8.2032	8.2099	8.2167	8.2234	8.2302	8.2369
.83	8.2437	8.2504	8.2572	8.2640	8.2707	8.2775	8.2842	8.2910	8.2978	8.3046
.84	8.3113	8.3181	8.3249	8.3317	8.3385	8.3452	8.3520	8.3588	8.3656	8.3724
.85	8.3792	8.3860	8.3928	8.3996	8.4064	8.4132	8.4200	8.4268	8.4336	8.4404
.86	8.4472	8.4540	8.4608	8.4677	8.4745	8.4813	8.4881	8.4949	8.5018	8.5086
.87	8.5154	8.5223	8.5291	8.5359	8.5428	8.5496	8.5564	8.5633	8.5701	8.5770
.88	8.5838	8.5907	8.5975	8.6044	8.6112	8.6181	8.6250	8.6318	8.6387	8.6455
.89	8.6524	8.6593	8.6661	8.6730	8.6799	8.6868	8.6936	8.7005	8.7074	8.7143
1.90	8.7212	8.7281	8.7349	8.7418	8.7487	8.7556	8.7625	8.7694	8.7763	8.7832
.91	8.7901	8.7970	8.8039	8.8108	8.8177	8.8246	8.8316	8.8385	8.8454	8.8523
.92	8.8592	8.8662	8.8731	8.8800	8.8869	8.8939	8.9008	8.9077	8.9147	8.9216
.93	8.9285	8.9355	8.9424	8.9494	8.9563	8.9633	8.9702	8.9772	8.9841	8.9911
.94	8.9980	9.0050	9.0119	9.0189	9.0259	9.0328	9.0398	9.0468	9.0537	9.0607
.95	9.0677	9.0747	9.0816	9.0886	9.0956	9.1026	9.1096	9.1165	9.1235	9.1305
.96	9.1375	9.1445	9.1515	9.1585	9.1655	9.1725	9.1795	9.1865	9.1935	9.2005
.97	9.2075	9.2145	9.2216	9.2286	9.2356	9.2426	9.2496	9.2567	9.2637	9.2707
.98	9.2777	9.2848	9.2918	9.2988	9.3059	9.3129	9.3199	9.3270	9.3340	9.3411
.99	9.3481	9.3552	9.3622	9.3693	9.3763	9.3834	9.3904	9.3975	9.4045	9.4116
2.00	9.4187	9.4257	9.4328	9.4399	9.4469	9.4540	9.4611	9.4682	9.4752	9.4823
.01	9.4894	9.4965	9.5036	9.5106	9.5177	9.5248	9.5319	9.5390	9.5461	9.5532
.02	9.5603	9.5674	9.5745	9.5816	9.5887	9.5958	9.6029	9.6100	9.6171	9.6243
.03	9.6314	9.6385	9.6456	9.6527	9.6599	9.6670	9.6741	9.6812	9.6884	9.6955
.04	9.7026	9.7098	9.7169	9.7240	9.7312	9.7383	9.7455	9.7526	9.7598	9.7669
.05	9.7741	9.7812	9.7884	9.7955	9.8027	9.8098	9.8170	9.8242	9.8313	9.8385
.06	9.8457	9.8528	9.8600	9.8672	9.8744	9.8815	9.8887	9.8959	9.9031	9.9103
.07	9.9174	9.9246	9.9318	9.9390	9.9462	9.9534	9.9606	9.9678	9.9750	9.9822
.08	9.9894	9.9966	10.004	10.011	10.018	10.025	10.033	10.040	10.047	10.054
.09	10.062	10.069	10.076	10.083	10.090	10.098	10.105	10.112	10.119	10.127
2.10	10.134	10.141	10.148	10.156	10.163	10.170	10.177	10.185	10.192	10.189
.11	10.206	10.214	10.221	10.228	10.235	10.243	10.250	10.257	10.264	10.272
.12	10.279	10.286	10.293	10.301	10.308	10.315	10.323	10.330	10.337	10.344
.13	10.352	10.359	10.366	10.374	10.381	10.388	10.396	10.403	10.410	10.417
.14	10.425	10.432	10.439	10.447	10.454	10.461	10.469	10.476	10.483	10.491
.15	10.498	10.505	10.513	10.520	10.527	10.535	10.542	10.549	10.557	10.564
.16	10.571	10.579	10.586	10.593	10.601	10.608	10.615	10.623	10.630	10.637
.17	10.645	10.652	10.659	10.667	10.674	10.682	10.689	10.696	10.704	10.711
.18	10.718	10.726	10.733	10.741	10.748	10.755	10.763	10.770	10.777	10.785
.19	10.792	10.800	10.807	10.814	10.822	10.829	10.837	10.844	10.851	10.859
2.20	10.866	10.874	10.881	10.888	10.896	10.903	10.911	10.918	10.926	10.933
.21	10.940	10.948	10.955	10.963	10.970	10.978	10.985	10.992	11.000	11.007
.22	11.015	11.022	11.030	11.037	11.045	11.052	11.059	11.067	11.074	11.082
.23	11.089	11.097	11.104	11.112	11.119	11.127	11.134	11.141	11.149	11.156
.24	11.164	11.171	11.179	11.186	11.194	11.201	11.209	11.216	11.224	11.231
.25	11.239	11.246	11.254	11.261	11.269	11.276	11.284	11.291	11.299	11.306
.26	11.314	11.321	11.329	11.336	11.344	11.351	11.359	11.366	11.374	11.381
.27	11.389	11.396	11.404	11.412	11.419	11.427	11.434	11.442	11.449	11.457
.28	11.464	11.472	11.479	11.487	11.494	11.502	11.510	11.517	11.525	11.532
.29	11.540	11.547	11.555	11.562	11.570	11.578	11.585	11.593	11.600	11.608

TABLE 3.—*Discharge over a thin-edged weir per foot of crest*—Continued.

and *H*, feet.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
2.30	11.615	11.623	11.631	11.638	11.646	11.653	11.661	11.669	11.676	11.684
.31	11.691	11.699	11.706	11.714	11.722	11.729	11.737	11.744	11.752	11.760
.32	11.767	11.775	11.783	11.790	11.798	11.805	11.813	11.821	11.828	11.836
.33	11.843	11.851	11.859	11.866	11.874	11.882	11.889	11.897	11.904	11.912
.34	11.920	11.927	11.935	11.943	11.950	11.958	11.966	11.973	11.981	11.989
.35	11.996	12.004	12.012	12.019	12.027	12.035	12.042	12.050	12.058	12.065
.36	12.073	12.081	12.088	12.096	12.104	12.111	12.119	12.127	12.134	12.142
.37	12.150	12.157	12.165	12.173	12.181	12.188	12.196	12.204	12.211	12.219
.38	12.227	12.234	12.242	12.250	12.258	12.265	12.273	12.281	12.288	12.296
.39	12.304	12.312	12.319	12.327	12.335	12.342	12.350	12.358	12.366	12.373
2.40	12.381	12.389	12.397	12.404	12.412	12.420	12.428	12.435	12.443	12.451
.41	12.459	12.466	12.474	12.482	12.490	12.497	12.505	12.513	12.521	12.528
.42	12.536	12.544	12.552	12.560	12.567	12.575	12.583	12.591	12.598	12.606
.43	12.614	12.622	12.630	12.637	12.645	12.653	12.661	12.669	12.676	12.684
.44	12.692	12.700	12.708	12.715	12.723	12.731	12.739	12.747	12.754	12.672
.45	12.770	12.778	12.786	12.794	12.801	12.809	12.817	12.825	12.833	12.840
.46	12.848	12.856	12.864	12.872	12.880	12.888	12.895	12.903	12.911	12.919
.47	12.927	12.935	12.942	12.950	12.958	12.966	12.974	12.982	12.990	12.997
.48	13.005	13.013	13.021	13.029	13.037	13.045	13.053	13.060	13.068	13.076
.49	13.084	13.092	13.100	13.108	13.116	13.124	13.131	13.139	13.147	13.155
2.50	13.163	13.171	13.179	13.187	13.195	13.202	13.210	13.218	13.226	13.234
.51	13.242	13.250	13.258	13.266	13.274	13.282	13.290	13.297	13.305	13.313
.52	13.321	13.329	13.337	13.345	13.353	13.361	13.369	13.377	13.385	13.393
.53	13.401	13.409	13.417	13.424	13.432	13.440	13.448	13.456	13.464	13.472
.54	13.480	13.488	13.496	13.504	13.512	13.520	13.528	13.536	13.544	13.552
.55	13.560	13.568	13.576	13.584	13.592	13.600	13.608	13.616	13.624	13.632
.56	13.640	13.648	13.656	13.664	13.672	13.680	13.688	13.696	13.704	13.712
.57	13.720	13.728	13.736	13.744	13.752	13.760	13.768	13.776	13.784	13.792
.58	13.800	13.808	13.816	13.824	13.832	13.840	13.848	13.856	13.864	13.872
.59	13.880	13.888	13.896	13.904	13.912	13.920	13.928	13.936	13.944	13.953
2.60	13.961	13.969	13.977	13.985	13.993	14.001	14.009	14.017	14.025	14.033
.61	14.041	14.049	14.057	14.065	14.074	14.082	14.090	14.098	14.106	14.114
.62	14.122	14.130	14.138	14.146	14.154	14.162	14.171	14.179	14.187	14.195
.63	14.203	14.211	14.219	14.227	14.235	14.243	14.252	14.260	14.268	14.276
.64	14.284	14.292	14.300	14.308	14.316	14.325	14.333	14.341	14.349	14.357
.65	14.356	14.373	14.382	14.390	14.398	14.406	14.414	14.422	14.430	14.438
.66	14.447	14.455	14.463	14.471	14.479	14.487	14.496	14.504	14.512	14.520
.67	14.528	14.536	14.545	14.553	14.561	14.569	14.577	14.585	14.594	14.602
.68	14.610	14.618	14.626	14.634	14.643	14.651	14.659	14.667	14.675	14.684
.69	14.692	14.700	14.708	14.716	14.725	14.733	14.741	14.749	14.757	14.766
2.70	14.774	14.782	14.790	14.798	14.807	14.815	14.823	14.831	14.839	14.848
.71	14.856	14.864	14.872	14.881	14.889	14.897	14.905	14.913	14.922	14.930
.72	14.938	14.946	14.955	14.963	14.971	14.979	14.988	14.996	15.004	15.012
.73	15.021	15.029	15.037	15.045	15.054	15.062	15.070	15.078	15.087	15.095
.74	15.103	15.112	15.120	15.128	15.136	15.145	15.153	15.161	15.169	15.178
.75	15.186	15.194	15.203	15.211	15.219	15.227	15.236	15.244	15.252	15.261
.76	15.269	15.277	15.285	15.294	15.302	15.310	15.319	15.327	15.335	15.344
.77	15.352	15.360	15.369	15.377	15.385	15.394	15.402	15.410	15.419	15.427
.78	15.435	15.443	15.452	15.460	15.468	15.477	15.485	15.494	15.502	15.510
.79	15.519	15.527	15.535	15.544	15.552	15.560	15.569	15.577	15.585	15.594

TABLE 3.—*Discharge over a thin-edged weir per foot of crest*—Continued.

Head *H*, feet.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
2.80	15.602	15.610	15.619	15.627	15.635	15.644	15.652	15.661	15.669	15.677
.81	15.686	15.694	15.702	15.711	15.719	15.728	15.736	15.744	15.753	15.761
.82	15.769	15.778	15.786	15.795	15.803	15.811	15.820	15.828	15.837	15.845
.83	15.853	15.862	15.870	15.879	15.887	15.895	15.904	15.912	15.921	15.929
.84	15.938	15.946	15.954	15.963	15.971	15.980	15.988	15.997	16.005	16.013
.85	16.022	16.030	16.039	16.047	16.056	16.064	16.072	16.081	16.089	16.098
.86	16.106	16.115	16.123	16.132	16.140	16.148	16.157	16.165	16.174	16.182
.87	16.191	16.199	16.208	16.216	16.225	16.233	16.242	16.250	16.258	16.267
.88	16.275	16.284	16.292	16.301	16.309	16.318	16.326	16.335	16.343	16.352
.89	16.360	16.369	16.377	16.386	16.394	16.403	16.411	16.420	16.428	16.437
2.90	16.445	16.454	16.462	16.471	16.479	16.488	16.496	16.505	16.513	16.522
.91	16.530	16.539	16.547	16.556	16.565	16.573	16.582	16.590	16.599	16.607
.92	16.616	16.624	16.633	16.641	16.650	16.658	16.667	16.675	16.684	16.692
.93	16.701	16.710	16.718	16.727	16.735	16.744	16.752	16.761	16.770	16.778
.94	16.787	16.795	16.804	16.812	16.821	16.830	16.838	16.847	16.855	16.864
.95	16.872	16.881	16.890	16.898	16.907	16.915	16.924	16.932	16.941	16.950
.96	16.958	16.967	16.975	16.984	16.993	17.001	17.010	17.018	17.027	17.036
.97	17.044	17.053	17.062	17.070	17.079	17.087	17.096	17.105	17.113	17.122
.98	17.130	17.139	17.148	17.156	17.165	17.174	17.182	17.191	17.199	17.208
.99	17.217	17.225	17.234	17.243	17.251	17.260	17.269	17.277	17.286	17.295
3.00	17.3033	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 4.—*Discharge over a thin-edged weir per foot of crest.*

Head *H*, feet.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	0.0000	0.0033	0.0094	0.0173	0.0266	0.0372	0.0489	0.0617	0.0753	0.0899
.1	.1053	.1215	.1384	.1561	.1744	.1935	.2131	.2334	.2543	.2758
.2	.2978	.3205	.3436	.3673	.3915	.4162	.4415	.4672	.4934	.5200
.3	.5472	.5748	.6028	.6313	.6602	.6895	.7193	.7495	.7800	.8110
.4	.8424	.8742	.9084	.9390	.9719	1.0052	1.0389	1.0730	1.1074	1.1422
.5	1.1773	1.2128	1.2487	1.2849	1.3214	1.3583	1.3955	1.4330	1.4709	1.5091
.6	1.5476	1.5865	1.6257	1.6652	1.7050	1.7451	1.7855	1.8262	1.8673	1.9086
.7	1.9503	1.9922	2.0344	2.0770	2.1198	2.1629	2.2063	2.2500	2.2940	2.3382
.8	2.3828	2.4276	2.4727	2.5180	2.5637	2.6096	2.6558	2.7022	2.7490	2.7959
.9	2.8432	2.8907	2.9385	2.9865	3.0348	3.0834	3.1322	3.1813	3.2306	3.2802
1.0	3.3300	3.3801	3.4304	3.4810	3.5318	3.5828	3.6342	3.6857	3.7375	3.7895
1.1	3.8418	3.8943	3.9470	4.0000	4.0532	4.1067	4.1604	4.2143	4.2384	4.3228
1.2	4.3774	4.4322	4.4873	4.5426	4.5981	4.6538	4.7098	4.7660	4.8224	4.8790
1.3	4.9358	4.9929	5.0502	5.1077	5.1654	5.2233	5.2814	5.3398	5.3984	5.4572
1.4	5.5162	5.5754	5.6348	5.6944	5.7542	5.8143	5.8745	5.9350	5.9957	6.0565
1.5	6.1176	6.1789	6.2404	6.3020	6.3633	6.4260	6.4883	6.5508	6.6135	6.6764
1.6	6.7394	6.8027	6.8662	6.9299	6.9937	7.0578	7.1221	7.1865	7.2512	7.3160
1.7	7.3810	7.4463	7.5117	7.5773	7.6431	7.7091	7.7752	7.8416	7.9081	7.9749
1.8	8.0418	8.1689	8.1762	8.2437	8.3113	8.3792	8.4172	8.5154	8.5838	8.6524
1.9	8.7212	8.7901	8.8592	8.9285	8.9980	9.0677	9.1375	9.2075	8.2777	9.3481

TABLE 4.—*Discharge over a thin-edged weir per foot of crest*—Continued.

Head *H*. feet.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
2.0	9.4187	9.4894	9.5603	9.6314	9.7026	9.7741	9.8457	9.9174	9.9894	10.0620
2.1	10.1340	10.2060	10.2790	10.3520	10.4250	10.4980	10.5710	10.6450	10.7180	10.7920
2.2	10.8660	10.9400	11.0150	11.0890	11.1640	11.2390	11.3140	11.3890	11.4640	11.5400
2.3	11.6150	11.6910	11.7670	11.8430	11.9200	11.9960	12.0730	12.1500	12.2270	12.3040
2.4	12.3810	12.4590	12.5360	12.6140	12.6920	12.7700	12.8480	12.9270	13.0050	13.0840
2.5	13.1630	13.2480	13.3210	13.4010	13.4800	13.5600	12.6400	13.7200	13.8000	13.8800
2.6	13.9610	14.0410	14.1220	14.2030	14.2840	14.3650	14.4470	14.5280	14.6100	14.6920
2.7	14.7740	14.8560	14.9380	15.0210	15.1030	15.1860	15.2690	15.3520	15.4350	15.5190
2.8	15.6020	15.6860	15.7690	15.8530	15.9380	16.0220	16.1060	16.1910	16.2750	16.3600
2.9	16.4450	16.5300	16.6160	16.7010	16.7870	16.8720	16.9580	17.0440	17.1300	17.2170
3.0	17.3033	17.3899	17.4698	17.5634	17.6503	17.7376	17.8248	17.9124	18.0000	18.0876
3.1	18.1754	18.2634	18.3516	18.4399	18.5285	18.6170	18.7056	18.7945	18.8838	18.9727
3.2	19.0619	19.1515	19.2410	19.3307	19.4206	19.5105	19.6007	19.6910	19.7812	19.8718
3.3	19.9624	20.0533	20.1442	20.2354	20.3267	20.4179	20.5095	20.6011	20.6930	20.7849
3.4	20.8777	20.9690	21.0613	21.1538	21.2464	21.3390	21.4319	21.5248	21.6180	21.7113
3.5	21.8045	21.8980	21.9917	22.0856	22.1795	22.2734	22.3677	22.4618	22.5564	22.6510
3.6	22.7456	22.8405	22.9354	23.0306	23.1259	23.2211	23.3167	23.4122	23.5081	23.6040
3.7	23.6999	23.7962	23.8924	23.9887	24.0852	24.1818	24.2787	24.3756	24.4728	24.5697
3.8	24.6673	24.7645	24.8621	24.9600	25.0576	25.1555	25.2537	25.3520	25.4502	25.5488
3.9	25.6473	25.7459	25.8748	25.9437	26.0429	26.1422	26.2414	26.3410	26.4405	26.5401
4.0	26.6400	26.7399	26.8401	26.9404	27.0406	27.1412	27.2417	27.3423	27.4432	27.5411
4.1	27.6453	27.7466	27.8478	27.9494	28.0509	28.1525	28.2544	28.3563	28.4582	29.5604
4.2	28.6626	28.7652	28.8678	28.9703	29.0732	29.1761	29.2790	29.3823	29.4855	29.5890
4.3	29.6926	29.7962	29.9001	30.0040	30.1079	30.2118	30.3163	30.4205	30.5251	30.6297
4.4	30.7342	30.8391	30.9440	31.0493	31.1545	31.2597	31.3649	31.4705	31.5764	31.6820
4.5	31.7878	31.8941	32.0003	32.1065	32.2128	32.3193	32.4259	32.5324	32.6393	32.7462
4.6	32.8534	32.9607	33.0679	33.1755	33.2830	33.3906	33.4985	33.6064	33.7143	33.8225
4.7	33.9307	34.0373	34.1475	34.2560	34.3646	34.4735	34.5824	34.6913	34.8005	34.9097
4.8	35.0193	35.1288	35.2354	35.3480	35.4578	35.5677	35.6780	35.7882	35.8984	36.0086
4.9	36.1182	36.2297	36.3406	36.4515	36.5624	36.6736	36.7845	36.8961	37.0073	37.1188
5.0	37.2304	37.3423	37.4542	37.5661	37.6783	37.7905	37.9027	38.0153	38.1275	38.2404
5.1	38.3529	38.4658	28.5787	38.6919	38.8052	38.9184	39.0319	39.1455	39.2591	39.3726
5.2	39.4865	39.6004	39.7146	39.8288	39.9430	40.0576	40.1718	40.2867	40.4012	40.5161
5.3	40.6310	40.7462	40.5281	40.9766	41.0919	41.2074	41.3230	41.4386	41.5544	41.6703
5.4	41.7866	41.9024	42.0186	42.1352	42.2517	42.3683	42.4848	42.6017	42.7186	42.8355
5.5	42.9523	43.0700	43.1871	43.3043	43.4219	42.5394	43.6573	43.7752	43.8931	44.0109
5.6	44.1292	44.2474	44.3659	44.4845	44.6030	44.7216	44.8404	44.9593	45.0782	45.1974
5.7	45.3166	45.4359	45.5554	45.6746	45.7945	45.9140	46.0339	46.1538	46.2740	46.3939
5.8	46.5141	46.6347	46.7552	46.8757	46.9963	47.1172	47.2380	47.3589	47.4798	47.6010
5.9	47.7226	47.8438	47.9653	48.0869	48.2084	48.3303	48.4522	48.5744	48.6963	48.8185
6.0	48.9407	49.0632	49.1858	49.3083	48.4312	49.5537	49.6766	49.7999	49.9230	50.0462
6.1	50.1694	50.2930	50.4162	50.5401	50.6637	50.7875	50.9114	51.0356	51.1595	51.2837
6.2	51.4082	51.5324	51.6570	51.7818	51.9034	52.0313	52.1531	52.2813	52.4062	52.5314
6.3	52.6570	52.7822	52.9077	53.0336	53.1591	53.2850	53.4109	53.5371	53.6630	53.7892
6.4	53.9157	54.0419	54.1684	54.2950	54.4219	54.5487	54.6756	54.8025	54.9297	55.0569
6.5	55.1832	55.3116	55.4392	55.5667	55.6943	55.8221	55.9500	56.0779	56.2061	56.3343
6.6	56.4625	56.5910	56.7192	56.8478	56.9766	57.1055	57.2340	57.3233	57.4921	57.6213
6.7	57.7505	57.8801	58.0093	58.1388	58.2687	58.3982	58.5281	58.6580	58.7882	58.9180
6.8	59.0482	59.1788	59.3090	59.4428	59.5700	59.7009	59.8314	59.9623	60.0935	60.2244
6.9	60.3556	60.4868	60.6183	60.7499	60.8814	61.0129	61.1445	61.2763	61.4082	61.5404

TABLE 4.—*Discharge over a thin-edged weir per foot of crest*—Continued.

Head *H*, feet.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
7.0	61.6736	61.8048	61.9370	62.0692	62.2017	62.3343	62.4671	62.6000	62.7329	62.8657
7.1	62.9986	63.1318	63.2650	63.3992	63.5317	63.6658	63.7991	63.9327	64.0665	64.2004
7.2	64.3343	64.4685	64.6027	64.7369	64.8711	65.0056	65.1398	65.2750	65.4095	65.5444
7.3	65.6798	65.8145	65.9498	66.0845	66.2197	66.3552	66.4908	63.6263	66.7618	66.8977
7.4	67.0336	67.1694	67.3053	67.4415	67.5777	67.7139	67.8504	67.9869	68.1235	68.2600
7.5	68.3969	68.5337	68.6706	68.8078	68.9447	69.0818	69.2794	69.3566	69.4941	69.6316
7.6	69.7695	69.9070	70.0449	70.1827	70.3209	70.4591	70.5973	70.7355	70.8737	71.0123
7.7	71.1508	71.2896	71.4282	71.5670	71.7059	71.8451	71.9843	72.1235	72.2627	72.4023
7.8	72.5414	72.6809	72.8208	72.9608	73.1002	73.2400	73.3802	73.5201	73.6603	73.8005
7.9	73.9410	74.0815	74.2220	74.3626	74.5031	74.6439	74.7848	74.9260	75.0669	75.2081
8.0	75.3492	75.4908	75.6320	75.7735	75.9150	76.0569	76.1987	76.3406	76.4824	76.6245
8.1	76.7665	76.9087	77.0509	77.1934	77.3360	77.4784	77.6210	77.7638	77.9067	78.0495
8.2	78.1924	78.3356	78.4788	78.6220	78.7655	78.9087	79.0522	79.1957	79.3396	79.4834
8.3	79.6273	79.7711	79.9158	80.0592	80.2034	80.3479	80.4921	80.6366	80.7811	80.9260
8.4	81.0705	81.2154	81.3602	81.5054	81.6508	81.7955	81.9406	82.0862	82.2314	82.3769
8.5	82.5224	82.6682	82.8141	82.9600	83.1058	83.2517	83.3979	83.5440	83.6902	83.8367
8.6	83.9833	84.1298	84.2763	84.4228	84.5697	84.7165	84.8634	85.0106	85.1578	85.3049
8.7	85.4521	85.5996	85.7472	85.8947	86.0455	86.1897	86.3376	86.4854	86.6336	86.7815
8.8	86.9297	87.0778	87.2264	87.3745	87.5231	87.6716	87.8204	87.9689	88.1178	88.2668
8.9	88.4192	88.5647	88.7139	88.8630	89.0126	89.1617	89.3113	89.4608	89.6108	89.7602
9.0	89.9100	90.0599	90.2064	90.3599	90.5101	90.6602	90.4778	90.9609	91.1115	91.2620
9.1	91.4125	91.5633	91.7142	91.8650	92.0159	92.1671	92.3183	92.4694	92.6206	92.7721
9.2	92.9237	93.0782	93.2267	93.3785	93.5304	93.6822	93.8341	93.9863	94.1384	94.2906
9.3	94.4428	94.5950	94.7475	94.9000	95.0529	95.2054	95.3582	95.5111	95.6639	95.8171
9.4	95.9703	96.1234	96.2766	96.4298	96.5833	96.7368	96.8903	97.0442	97.1977	97.3516
9.5	97.5057	97.6596	97.8138	97.9679	98.1021	98.2763	98.4308	98.5858	98.7398	98.8943
9.6	99.0492	99.2040	99.3589	99.5141	99.6689	99.8241	99.9793	100.1344	100.2899	100.4455
9.7	100.6010	100.7565	100.9123	101.0678	101.2237	101.3799	101.5357	101.6919	101.8481	102.0042
9.8	102.1607	102.3169	102.4734	102.6299	102.7868	102.9433	103.1001	103.2570	103.4141	103.5710
9.9	103.7282	103.8853	104.0429	104.2000	104.3575	104.5121	104.6726	104.8304	104.9882	105.1461
10.0	105.3039	105.4618	105.6199	105.7781	105.9363	106.0945	106.2530	106.4115	106.5700	106.7285

When applied to a weir with N end contractions, the measured crest length L' should be reduced by the formula

$$L = L' - 0.1\,NH$$

When applied to a weir having appreciable velocity of approach, the measured head should be corrected by the correction formula of Francis (see p. 15), or by one of the simpler approximate equivalents; or the correction may be applied as a percentage to the discharge, by the use of Table 2.

Table 3, taken from Lowell Hydraulic Experiments, by James B. Francis, gives the discharge for heads from zero to 3 feet, advancing by thousandths.

Table 4 is original and gives the discharge for heads from zero to 10.09 feet, advancing by hundredths.

By increasing the quantities from either table 1 per cent, the discharge by the Cippoletti formula will be obtained,

$$Q=3.36\tfrac{2}{3}\ LH^{\frac{3}{2}}.$$

In calculating discharge by this formula, the head should be corected for velocity of approach by the formula

$$H=D+1.5h.$$

TABLES 5 AND 6.—THREE-HALVES POWERS.

These tables of three-halves powers (cubes of the square roots) were repared by the writer to facilitate the calculation of discharge over reirs of various forms, by the use of coefficients taken from the iagrams that accompany this paper and the base formula

$$Q=CLH^{\frac{3}{2}}.$$

TABLE 5.—*Three-halves powers for numbers 0 to 1.49.*

Numbers.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	.010
0.00	0.0000	0.0001	0.0002	0.0003	0.0004	0.0005	0.0006	0.0007	0.0008	0.0009	0.0010
.01	.0010	.00118	.00136	.00154	.00172	.00190	.00208	.00236	.00244	.00262	.0028
.02	.0028	.00304	.00328	.00352	.00376	.00400	.00424	.00448	.00472	.00496	.0052
.03	.0052	.00548	.00576	.00604	.00632	.00660	.00688	.00716	.00744	.00772	.0080
.04	.0080	.00832	.00864	.00896	.00928	.00960	.00992	.01024	.01056	.01088	.0112
.05	.0112	.01155	.01190	.01225	.01260	.01295	.01330	.01365	.01400	.01435	.0147
.06	.0147	.01508	.01546	.01584	.01622	.01660	.01698	.01736	.01774	.01812	.0185
.07	.0185	.01891	.01932	.01973	.02014	.02055	.02096	.02137	.02178	.02219	.0226
.08	.0226	.02304	.02348	.02392	.02436	.02480	.02524	.02568	.02612	.02656	.0270
.09	.0270	.02746	.02792	.02838	.02884	.02930	.02976	.03022	.03068	.03114	.0316
0.10	0.0316	0.03209	0.03258	0.03307	0.03356	0.03405	0.03454	0.03503	00355.2	0.03601	0.0365
.11	.0365	.03701	.03752	.03803	.03854	.03905	.03956	.04007	.04058	.04109	.0416
.12	.0416	.04213	.04266	.04319	.04372	.04425	.04478	.04531	.04584	.04637	.0469
.13	.0469	.04745	.04800	.04855	.04910	.04965	.05020	.05075	.05130	.05185	.0524
.14	.0524	.05297	.05354	.05411	.05468	.05525	.05582	.05639	.05696	.05753	.0581
.15	.0581	.05869	.05928	.05987	.06046	.06105	.06164	.06223	.06282	.06341	.0640
.16	.0640	.06451	.06522	.06583	.06644	.06705	.06766	.06827	.06888	.06949	.0701
.17	.0701	.07073	.07136	.07199	.07262	.07325	.07388	.07451	.07514	.07577	.0764
.18	.0764	.07704	.07768	.07832	.07896	.07960	.08024	.08088	.08152	.08216	.0828
.19	.0828	.08346	.08412	.08478	.08544	.08610	.08676	.08742	.08808	.08874	.0894
0.20	0.0894	0.09008	0.09076	0.09144	0.09212	0.09280	0.09348	0.09416	0.09484	009552	0.0962
.21	.0962	.09690	.09760	.09830	.09900	.09970	.10040	.10110	.1018	.1025	.1032
.22	.1032	.10391	.10462	.10533	.10604	.10675	.10746	.10817	.10888	.10959	.1103
.23	.1103	.11103	.11176	.11249	.11322	.11395	.11468	.11541	.11614	.11687	.1176
.24	.1176	.11834	.11908	.11982	.12506	.12130	.12204	.12278	.12352	.12426	.1250
.25	.1250	.12576	.12652	.12728	.12804	.12880	.12956	.13032	.13108	.13184	.1326
.26	.1326	.13337	.13414	.13491	.13568	.13645	.13722	.13799	.13876	.13953	.1403
.27	.1403	.14109	.14188	.14267	.14346	.14425	.14504	.14583	.14662	.14741	.1482
.28	.1482	.1490	.1498	.1506	.1514	.1522	1530	.1538	.1546	.1554	.1562
.29	.1562	.15701	.15782	.15863	.15944	.16025	.16106	.16187	.16268	.16349	.1643

TABLE 5.—*Three-halves powers for numbers 0 to 1.49*—Continued.

Numbers.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	.010
0.30	0.1643	0.16513	0.16596	0.16679	0.16762	0.16845	0.16928	0.17011	0.17094	0.17177	0.1726
.31	.1726	.17344	.17428	.17512	.17596	.17680	.17764	.17848	.17932	.18016	.1810
.32	.1810	.18186	.18272	.18358	.18444	.18530	.18616	.18702	.18788	.18874	.1896
.33	.1896	.19047	.19134	.19221	.19308	.19395	.19482	.19569	.19656	.19743	.1983
.34	.1983	.19918	.20006	.20094	.20182	.20270	.20358	.20446	.20534	.20622	.2071
.35	.2071	.20799	.20888	.20977	.21066	.21155	.21244	.21333	.21422	.21511	.2160
.36	.2160	.21691	.21782	.21873	.21964	.22055	.22146	.22237	.22328	.22419	.2251
.37	.2251	.22601	.22692	.22783	.22874	.22965	.23056	.2317	.23238	.23329	.2342
.38	.2342	.23514	.23608	.23702	.23796	.23890	.23984	.24078	.24172	.24266	.2436
.39	.2436	.24454	.24548	.24642	.24736	.24830	.24924	.25018	.25112	.25206	.2530
0.40	0.2530	0.25395	0.25490	0.25585	0.25680	0.25775	0.25870	0.25965	0.26060	0.26155	0.2625
.41	.2625	.26347	.26444	.26541	.26638	.26735	.26832	.26929	.27026	.27123	.2722
.42	.2722	.27318	.27416	.27514	.27612	.27710	.27808	.27906	.28004	.28102	.2820
.43	.2820	.28299	.28397	.28497	.28596	.28695	.28794	.28893	.28992	.29091	.2919
.44	.2919	.2929	.2939	.2949	.2959	.2969	.2979	.2989	.2999	.3009	.3019
.45	.3019	.30291	.30392	.30493	.30594	.30695	.30796	.30897	.30998	.31099	.3120
.46	.3120	.31302	.31404	.31506	.31608	.31710	.31812	.31914	.32016	.32118	.3222
.47	.3222	.32323	.32426	.32529	.32632	.32735	.32838	.32941	.33044	.33147	.3325
.48	.3325	.33355	.33460	.33565	.33670	.33775	.33880	.33985	.34090	.34195	.3430
.49	.3430	.34406	.34512	.34618	.34724	.3483	.34936	.35042	.35148	.35254	.3536
0.50	0.3536	0.35466	0.35572	0.35678	0.35784	0.35890	0.35996	0.36102	0.36208	0.36314	0.3642
.51	.3642	.36528	.36636	.36744	.36852	.36960	.37068	.37176	.37284	.37392	.3750
.52	.3750	.37608	.37716	.37824	.37932	.38040	.38148	.38256	.38364	.38472	.3858
.53	.3858	.38690	.38800	.38910	.39020	.39130	.39240	.39350	.39460	.3957	.3968
.54	.3968	.39791	.39902	.40013	.40124	.40235	.40346	.40457	.40568	.40679	.4079
.55	.4079	.40902	.41014	.41126	.41238	.41350	.41462	.41574	.41686	.41798	.4191
.56	.4191	.42022	.42134	.42246	.42358	.42470	.42582	.42694	.42806	.42918	.4303
.57	.4303	.43144	.43258	.43372	.43486	.43600	.43714	.43828	.43942	.44056	.4417
.58	.4417	.44285	.44400	.44515	.44630	.44745	.44860	.44975	.45090	.45205	.4532
.59	.4532	.45436	.45552	.45668	.45784	.45900	.46016	.46132	.46248	.46364	.4648
0.60	0.4648	0.46596	0.46712	0.46828	0.46944	0.47060	0.47176	0.47292	0.47408	0.47524	0.4764
.61	.4764	.47758	.47876	.47994	.48112	.48230	.48348	.48466	.48584	.48702	.4882
.62	.4882	.48938	.49056	.49174	.49292	.49410	.49528	.49646	.49764	.49882	.5000
.63	.5000	.50120	.50240	.5036	.5048	.5060	.5072	.5084	.5096	.5108	.5120
.64	.5120	.5132	.5144	.5156	.5168	.5180	.5192	.5204	.5216	.5228	.5240
.65	.5240	.52522	.52644	.52766	.52888	.53010	.53132	.53254	.53376	.53498	.5362
.66	.5362	.53742	.53864	.53986	.54108	.54230	.54352	.54474	.54596	.54718	.5484
.67	.5484	.54963	.55086	.55209	.55332	.55455	.55578	.55701	.55824	.55947	.5607
.68	.5607	.56195	.56320	.56445	.56570	.56695	.56820	.56945	.57070	.57195	.5732
.69	.5732	.57445	.5757	.57695	.57820	.57945	.58070	.58195	.58320	.58445	.5857
0.70	0.5857	0.58696	0.58822	0.58948	0.59074	0.59200	0.59326	0.59452	0.59578	0.59704	0.5983
.71	.5983	.59956	.60082	.60208	.60334	.60460	.60586	.60712	.60838	.60964	.6109
.72	.6109	.61218	.61346	.61474	.61602	.61730	.61858	.61986	.62114	.62242	.6237
.73	.6237	.62499	.62628	.62757	.62886	.63015	.63144	.63273	.63402	.63531	.6366
.74	.6366	.63789	.63918	.64047	.64176	.64305	.64434	.64563	.64692	.64821	.6495
.75	.6495	.65081	.65212	.65343	.65474	.65605	.65736	.65867	.65998	.66129	.6626
.76	.6626	.66391	.66522	.66653	.66784	.66915	.67046	.67177	.67308	.67439	.6757
.77	.6757	.67702	.67834	.67966	.68098	.68230	.68362	.68494	.68626	.68758	.6889
.78	.6889	.69023	.69156	.69289	.69422	.69555	.69688	.69821	.69954	.70087	.7022
.79	.7022	.70353	.70486	.70619	.70752	.70885	.71018	.71151	.71284	.71417	.7155

TABLE 5.—*Three-halves powers for numbers 0 to 1.49*—Continued.

Numbers.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	.010
0.80	0.7155	0.71685	0.71820	0.71955	0.72090	0.72225	0.72360	0.72495	0.72630	0.72765	0.7290
.81	.7290	.73035	.7317	.73305	.73440	.73575	.73710	.73845	.73980	.74115	.7425
.82	.7425	.74387	.74524	.74661	.74798	.74935	.75072	.75209	.75346	.75483	.7562
.83	.7562	.75757	.75894	.76031	.76168	.76305	.76443	.76579	.76716	.76853	.7699
.84	.7699	.77128	.77266	.77404	.77542	.77680	.77818	.77956	.78094	.78232	.7837
.85	.7837	.78508	.78646	.78784	.78922	.79060	.99198	.79336	.79474	.79612	.7975
.86	.7975	.79890	.80030	.80170	.8031	.8045	.8059	.8073	.8087	.8101	.8115
.87	.8115	.8129	.8143	.8157	.8171	.8185	.8199	.8213	.8227	.8241	.8255
.88	.8255	.82691	.82832	.82973	.83114	.83255	.83396	.83537	.83678	.83819	.8396
.89	.8396	.84102	.84244	.84386	.84528	.84670	.84812	.84954	.85096	.85238	.8538
0.90	0.8538	0.85523	0.85666	0.85809	0.85952	0.86095	0.86238	0.86381	0.86524	0.86667	0.8681
.91	.8681	.86953	.87096	.87239	.87382	.87525	.87668	.87811	.87954	.88097	.8824
.92	.8824	.88385	.8853	.88675	.88820	.88965	.89110	.89255	.8940	.89545	.8969
.93	.8969	.89835	.89980	.90125	.90270	.90415	.9056	.90705	.9085	.90995	.9114
.94	.9114	.91285	.9143	.91575	.91720	.91865	.92010	.92155	.9230	.92445	.9259
.95	.9259	.92737	.92884	.93081	.93178	.93325	.93472	.93619	.93766	.93913	.9406
.96	.9406	.94207	.94354	.94501	.94648	.94795	.94942	.95089	.95236	.95383	.9553
.97	.9553	.95679	.95828	.95977	.96126	.96275	.96424	.96573	.96722	.96871	.9702
.98	.9702	.97168	.97316	.97464	.97612	.97760	.97908	.98056	.98204	.98352	.9850
.99	.9850	.9865	.9880	.9895	.9910	.9925	.9940	.9955	.9970	.9985	1.0000
1.00	1.0000	1.0015	1.0030	1.0045	1.0060	1.0075	1.0090	1.0105	1.0120	1.0135	1.0150
1.01	1.0150	1.01652	1.01804	1.01956	1.02108	1.02260	1.02412	1.02564	1.02716	1.02868	1.0302
1.02	1.0302	1.03171	1.03322	1.03473	1.03624	1.03775	1.03926	1.04077	1.04282	1.04379	1.0453
1.03	1.0453	1.04683	1.04836	1.04989	1.05142	1.05295	1.05448	1.05601	1.05754	1.05907	1.0606
1.04	1.0606	1.06213	1.06366	1.06519	1.06672	1.06825	1.06978	1.07131	1.07284	1.07437	1.0759
1.05	1.0759	1.07744	1.07898	1.08052	1.08206	1.08360	1.08514	1.08668	1.08822	1.08976	1.0913
1.06	1.0913	1.09285	1.09440	1.09595	1.09750	1.09905	1.10060	1.10215	1.10370	1.10525	1.1068
1.07	1.1068	1.10836	1.10992	1.11148	1.11304	1.11460	1.11616	1.11772	1.11928	1.12084	1.1224
1.08	1.1224	1.12396	1.12552	1.12708	1.12864	1.13020	1.13176	1.13332	1.13488	1.13644	1.1380
1.09	1.1380	1.13957	1.14114	1.14271	1.14428	1.14585	1.14742	1.14899	1.15056	1.15213	1.1537
1.10	1.1537	1.15528	1.15686	1.15844	1.16002	1.16160	1.16318	1.16476	1.16634	1.16792	1.1695
1.11	1.1695	1.17108	1.17266	1.17424	1.17582	1.17740	1.17898	1.18056	1.18214	1.18372	1.1853
1.12	1.1853	1.18689	1.18848	1.19007	1.19166	1.19325	1.19484	1.19643	1.19802	1.19961	1.2012
1.13	1.2012	1.20280	1.20440	1.20600	1.20760	1.20920	1.21080	1.21240	1.21400	1.21560	1.2172
1.14	1.2172	1.21880	1.22040	1.22200	1.22360	1.22520	1.22680	1.22840	1.23000	1.23160	1.2332
1.15	1.2332	1.23482	1.23644	1.23806	1.23968	1.24130	1.24292	1.24454	1.24616	1.24778	1.2494
1.16	1.2494	1.25102	1.25264	1.25426	1.25588	1.25750	1.25912	1.26074	1.26236	1.26398	1.2656
1.17	1.2656	1.26722	1.26884	1.27046	1.27208	1.27370	1.27532	1.27694	1.27856	1.28018	1.2818
1.18	1.2818	1.28343	1.28506	1.28669	1.28832	1.28995	1.29158	1.29321	1.29484	1.29647	1.2981
1.19	1.2981	1.29974	1.30138	1.30302	1.30466	1.30630	1.30794	1.30958	1.31122	1.31286	1.3145
1.20	1.3145	1.31615	1.31780	1.31945	1.32110	1.32275	1.32440	1.32605	1.32770	1.32935	1.3310
1.21	1.3310	1.33265	1.33430	1.33595	1.33760	1.33925	1.34090	1.34255	1.34420	1.34585	1.3475
1.22	1.3475	1.34916	1.35082	1.35248	1.35414	1.35580	1.35746	1.35912	1.36078	1.36244	1.3641
1.23	1.3641	1.36577	1.36744	1.36911	1.37078	1.37245	1.37412	1.37579	1.37746	1.37913	1.3808
1.24	1.3808	1.38247	1.38414	1.38581	1.38748	1.38915	1.39082	1.39249	1.39416	1.39583	1.3975
1.25	1.3975	1.39919	1.40088	1.40257	1.40426	1.40595	1.40764	1.40933	1.41102	1.41271	1.4144
1.26	1.4144	1.41608	1.41776	1.41944	1.42112	1.42280	1.42448	1.42616	1.42784	1.42952	1.4312
1.27	1.4312	1.4329	1.4346	1.4363	1.4380	1.4397	1.4414	1.4431	1.4448	1.4465	1.4482
1.28	1.4482	1.4499	1.4516	1.4533	1.4550	1.4567	1.4584	1.4601	1.4618	1.4635	1.4652
1.29	1.4652	1.4669	1.4686	1.4703	1.4720	1.4737	1.4754	1.4771	1.4788	1.4805	1.4822

TABLE 5.—*Three-halves powers for numbers 0 to 1.49*—Continued.

Numbers.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	.010
1.30	1.4822	1.48392	1.48564	1.48736	1.48908	1.49080	1.49252	1.49424	1.49596	1.49768	1.4994
1.31	1.4994	1.50112	1.50284	1.50456	1.50628	1.50800	1.50972	1.51144	1.51316	1.51488	1.5166
1.32	1.5166	1.51832	1.52004	1.52176	1.52348	1.52520	1.52692	1.52864	1.53036	1.53208	1.5338
1.33	1.5338	1.53554	1.53728	1.53902	1.54076	1.54250	1.54424	1.54598	1.54772	1.54946	1.5512
1.34	1.5512	1.55294	1.55468	1.55642	1.55816	1.55990	1.56164	1.56338	1.56512	1.56686	1.5686
1.35	1.5686	1.57034	1.57208	1.57382	1.57556	1.57730	1.57904	1.58078	1.58252	1.58426	1.5860
1.36	1.5860	1.58775	1.58950	1.59125	1.59300	1.59475	1.59650	1.59825	1.60000	1.60175	1.6035
1.37	1.6035	1.60526	1.60702	1.60878	1.61054	1.61230	1.61406	1.61582	1.61758	1.61934	1.6211
1.38	1.6211	1.62287	1.62464	1.62641	1.62818	1.62995	1.63172	1.63349	1.63526	1.63703	1.6388
1.39	1.6388	1.64057	1.64234	1.64411	1.64588	1.64765	1.64942	1.65119	1.65296	1.65473	1.6565
1.40	1.6565	1.65828	1.66006	1.66184	1.66362	1.66540	1.66718	1.66896	1.67075	1.67252	1.6743
1.41	1.6743	1.67608	1.67786	1.67964	1.68142	1.68320	1.68498	1.68676	1.68854	1.69032	1.6921
1.42	1.6921	1.69389	1.69568	1.69747	1.69926	1.70105	1.70284	1.70463	1.70642	1.70821	1.7100
1.43	1.7100	1.7118	1.7136	1.7154	1.7172	1.7190	1.7208	1.7226	1.7244	1.7262	1.7280
1.44	1.7280	1.7298	1.7316	1.7334	1.7352	1.7370	1.7388	1.7406	1.7424	1.7442	1.7460
1.45	1.7460	1.74781	1.74962	1.75143	1.75324	1.75505	1.75686	1.75867	1.76048	1.76229	1.7641
1.46	1.7641	1.76592	1.76774	1.76956	1.77138	1.77320	1.77502	1.77684	1.77866	1.78048	1.7823
1.47	1.7823	1.78412	1.78594	1.78776	1.78958	1.79140	1.79322	1.79504	1.79686	1.79868	1.8005
1.48	1.8005	1.80233	1.80416	1.80599	1.80782	1.80965	1.81148	1.81331	1.81514	1.81697	1.8188
1.49	1.8188	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 6.—*Three-halves powers for numbers from 0 to 12.*

Units. / Hundredths.	0	1	2	3	4	5	6	7	8	9	10	11
0.00	0.0000	1.0000	2.8284	5.1962	8.0000	11.1803	14.6969	18.5203	22.6274	27.0000	31.6228	36.4829
.01	.0010	1.0150	2.8497	5.2222	8.0300	11.2139	14.7337	18.5600	22.6699	27.0450	31.6702	36.5326
.02	.0028	1.0302	2.8710	5.2482	8.0601	11.2475	14.7705	18.5997	22.7123	27.0890	31.7177	36.5824
.03	.0052	1.0453	2.8923	5.2743	8.0902	11.2811	14.8073	18.6394	22.7548	27.1351	31.7652	36.6322
.04	.0080	1.0606	2.9137	5.3004	8.1203	11.3148	14.8442	18.6792	22.7973	27.1802	31.8127	36.6820
.05	.0112	1.0759	2.9352	5.3266	8.1505	11.3485	14.8810	18.7190	22.8399	27.2253	31.8602	36.7319
.06	.0147	1.0913	2.9567	5.3528	8.1807	11.3822	14.9179	18.7589	22.8825	27.2705	31.9078	36.7818
.07	.0185	1.1068	2.9782	5.3791	8.2109	11.4160	14.9549	18.7988	22.9251	27.3156	31.9554	36.8317
.08	.0226	1.1224	2.9998	5.4054	8.2412	11.4497	14.9919	18.8387	22.9677	27.3608	32.0030	36.8816
.09	.0270	1.1380	3.0215	5.4317	8.2715	11.4836	15.0289	18.8786	23.0103	27.4060	32.0506	36.9315
0.10	0.0316	1.1537	3.0432	5.4581	8.3019	11.5174	15.0659	18.9185	23.0530	27.4512	32.0983	36.9815
.11	.0365	1.1695	3.0650	5.4845	8.3323	11.5513	15.1030	18.9585	23.0957	27.4965	32.1460	37.0315
.12	.0416	1.1853	3.0868	5.5110	8.3627	11.5852	15.1400	18.9985	23.1384	27.5418	32.1937	37.0815
.13	.0469	1.2012	3.1086	5.5375	8.3932	11.6192	15.1772	19.0386	23.1812	27.5871	32.2414	37.1315
.14	.0524	1.2172	3.1306	5.5641	8.4237	11.6532	15.2143	19.0786	23.2240	27.6324	32.2892	37.1816
.15	.0581	1.2332	3.1525	5.5907	8.4542	11.6872	15.2515	19.1187	23.2668	27.6778	32.3370	37.2317
.16	.0640	1.2494	3.1745	5.6173	8.4848	11.7213	15.2887	19.1589	23.3096	27.7232	32.3848	37.2817
.17	.0701	1.2656	3.1966	5.6440	8.5154	11.7554	15.3260	19.1990	23.3525	27.7686	32.4326	37.3319
.18	.0764	1.2818	3.2187	5.6708	8.5460	11.7895	15.3632	19.2392	23.3954	27.8140	32.4804	37.3820
.19	.0828	1.2981	3.2409	5.6975	8.5767	11.8236	15.4005	19.2794	23.4383	27.8595	32.5283	37.4322

TABLE 6.—*Three-halves powers for numbers from 0 to 12*—Continued.

Units / Hundredths	0	1	2	3	4	5	6	7	8	9	10	11
0.20	0.0894	1.3145	3.2631	5.7243	8.6074	11.8578	15.4379	19.3196	23.4812	27.9050	32.5762	37.4824
.21	.0962	1.3310	3.2854	5.7512	8.6382	11.8920	15.4752	19.3599	23.5242	27.9514	32.6241	37.5326
.22	.1032	1.3475	3.3077	5.7781	8.6690	11.9263	15.5126	19.4002	23.5672	27.9960	32.6720	37.5828
.23	.1103	1.3641	3.3301	5.8050	8.6998	11.9606	15.5501	19.4405	23.6102	28.0416	32.7200	37.6331
.24	.1176	1.3808	3.3525	5.8320	8.7307	11.9949	15.5866	19.4808	23.6533	28.0872	32.7680	37.6833
.25	.1250	1.3975	3.3750	5.8590	8.7616	12.0293	15.6250	19.5212	23.6963	28.1328	32.8160	37.7336
.26	.1326	1.4144	3.3975	5.8861	8.7925	12.0636	15.6616	19.5576	23.7394	28.1784	32.8640	37.7840
.27	.1403	1.4312	3.4201	5.9132	8.8235	12.0981	15.7001	19.6021	23.7825	28.2241	32.9121	37.8343
.28	.1482	1.4482	3.4427	5.9403	8.8545	12.1325	15.7376	19.6425	23.8257	28.2698	32.9600	37.8847
.29	.1562	1.4652	3.4654	5.9675	8.8856	12.1670	15.7752	19.6830	23.8689	28.3155	33.0083	37.9351
0.30	0.1643	1.4822	3.4881	5.9947	8.9167	12.2015	15.8129	19.7235	23.9121	28.3612	33.0564	37.9855
.31	.1726	1.4994	3.5109	6.0220	8.9478	12.2361	15.8505	19.7641	23.9553	28.4069	33.1046	38.0359
.32	.1810	1.5166	3.5337	6.0493	8.9790	12.2706	15.8882	19.8046	23.9986	28.4527	33.1527	38.0864
.33	.1896	1.5338	3.5566	6.0767	9.0102	12.3053	15.9260	19.8452	24.0418	28.4985	33.2009	38.1369
.34	.1983	1.5512	3.5795	6.1041	9.0414	12.3399	15.9637	19.8858	24.0851	28.5444	33.2492	38.1874
.35	.2071	1.5686	3.6025	6.1315	9.0726	12.3746	16.0015	19.9265	24.1285	28.5902	33.2974	38.2379
.36	.2160	1.5860	3.6255	6.1590	9.1040	12.4093	16.0393	19.9672	24.1718	28.6361	33.3457	38.2884
.37	.2251	1.6035	3.6486	6.1865	9.1353	12.4440	16.0772	20.0079	24.2152	28.6820	33.3940	38.3390
.38	.2342	1.6211	3.6717	6.2141	9.1667	12.4788	16.1150	20.0486	24.2586	28.7279	33.4423	38.3896
.39	.2436	1.6388	3.6949	6.2417	9.1981	12.5136	16.1529	20.0894	24.3021	28.7739	33.4906	38.4402
0.40	0.2530	1.6565	3.7181	6.2693	9.2295	12.5485	16.1909	20.1302	24.3455	28.8199	33.5390	38.4908
.41	.2625	1.6743	3.7413	6.2970	9.2610	12.5833	16.2288	20.1710	24.3890	28.8659	33.5874	38.5415
.42	.2722	1.6921	3.7646	6.3247	9.2925	12.6182	16.2668	20.2118	24.4325	28.9119	33.6358	38.5922
.43	.2820	1.7100	3.7880	6.3525	9.3241	12.6532	16.3048	20.2527	24.4761	28.9579	33.6842	38.6429
.44	.2919	1.7280	3.8114	6.3803	9.3557	12.6882	16.3429	20.2936	24.5196	29.0040	33.7327	38.6936
.45	.3019	1.7460	3.8349	6.4081	9.3873	12.7232	16.3810	20.3345	24.5632	29.0501	33.7811	38.7443
.46	.3120	1.7641	3.8584	6.4360	9.4189	12.7582	16.4191	20.3755	24.6068	29.0962	33.8297	38.7951
.47	.3222	1.7823	3.8819	6.4639	9.4506	12.7933	16.4572	20.4165	24.6505	29.1424	33.8782	38.8459
.48	.3325	1.8005	3.9055	6.4919	9.4824	12.8284	16.4954	20.4575	24.6941	29.1885	33.9267	38.8967
.49	.3430	1.8188	3.9292	6.5199	9.5141	12.8635	16.5336	20.4985	24.7378	29.2347	33.9753	38.9475
0.50	0.3536	1.8371	3.9529	6.5479	9.5459	12.8986	16.5718	20.5396	24.7815	29.2810	34.0239	38.9984
.51	.3642	1.8555	3.9766	6.5760	9.5778	12.9338	16.6101	20.5807	24.8253	29.3272	34.0725	39.0493
.52	.3750	1.8740	4.0004	6.6041	9.6097	12.9691	16.6484	20.6218	24.8691	29.3735	34.1211	39.1002
.53	.3858	1.8925	4.0242	6.6323	9.6416	13.0043	16.6867	20.6630	24.9129	29.4198	34.1698	39.1511
.54	.3968	1.9111	4.0481	6.6605	9.6735	13.0396	16.7250	20.7041	24.9567	29.4661	34.2185	39.2020
.55	.4079	1.9297	4.0720	6.6887	9.7055	13.0749	16.7634	20.7453	25.0005	29.5124	34.2672	39.2530
.56	.4191	1.9484	4.0960	6.7170	9.7375	13.1103	16.8018	20.7866	25.0444	29.5588	34.3159	39.3040
.57	.4303	1.9672	4.1200	6.7453	9.7695	13.1457	16.8402	20.8278	25.0883	29.6052	34.3647	39.3550
.58	.4417	1.9860	4.1441	6.7737	9.8016	13.1811	16.8787	20.8691	25.1322	29.6516	34.4135	39.4060
.59	.4532	2.0049	4.1682	6.8021	9.8337	13.2165	16.9172	20.9104	25.1762	29.6980	34.4623	39.4571
0.60	0.4648	2.0238	4.1924	6.8305	9.8659	13.2520	16.9557	20.9518	25.2202	29.7445	34.5111	39.5082
.61	.4764	2.0429	4.2166	6.8590	9.8981	13.2875	16.9943	20.9931	25.2642	29.7910	34.5599	39.5593
.62	.4882	2.0619	4.2408	6.8875	9.9303	13.3231	17.0328	21.0345	25.3082	29.8375	34.6088	39.6104
.63	.5000	2.0810	4.2651	6.9161	9.9626	13.3587	17.0714	21.0759	25.3522	29.8841	34.6577	39.6615
.64	.5120	2.1002	4.2895	6.9447	9.9949	13.3943	17.1101	21.1174	25.3963	29.9306	34.7066	39.7127
.65	.5240	2.1195	4.3139	6.9733	10.0272	13.4299	17.1488	21.1589	25.4404	29.9772	34.7557	39.7639
.66	.5362	2.1388	4.3383	7.0020	10.0596	13.4656	17.1874	21.2004	25.4845	30.0238	34.8045	39.8151
.67	.5484	2.1581	4.3628	7.0307	10.0920	13.5013	17.2172	21.2419	25.5287	30.0704	34.8535	39.8663
.68	.5607	2.1775	4.3874	7.0595	10.1244	13.5370	17.2649	21.2834	25.5729	30.1171	34.9025	39.9176
.69	.5732	2.1970	4.4119	7.0883	10.1569	13.5728	17.3037	21.3250	25.6171	30.1638	34.9516	39.9689

TABLE 5.—*Three-halves powers for numbers 0 to 1.49*—Continued.

Numbers.	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	.010
1.30	1.4822	1.48392	1.48564	1.48736	1.48908	1.49080	1.49252	1.49424	1.49596	1.49768	1.4994
1.31	1.4994	1.50112	1.50284	1.50456	1.50628	1.50800	1.50972	1.51144	1.51316	1.51488	1.5166
1.32	1.5166	1.51832	1.52004	1.52176	1.52348	1.52520	1.52692	1.52864	1.53036	1.53208	1.5338
1.33	1.5338	1.53554	1.53728	1.53902	1.54076	1.54250	1.54424	1.54598	1.54772	1.54946	1.5512
1.34	1.5512	1.55294	1.55468	1.55642	1.55816	1.55990	1.56164	1.56338	1.56512	1.56686	1.5686
1.35	1.5686	1.57034	1.57208	1.57382	1.57556	1.57730	1.57904	1.58078	1.58252	1.58426	1.5860
1.36	1.5860	1.58775	1.58950	1.59125	1.59300	1.59475	1.59650	1.59825	1.60000	1.60175	1.6035
1.37	1.6035	1.60526	1.60702	1.60878	1.61054	1.61230	1.61406	1.61582	1.61758	1.61934	1.6211
1.38	1.6211	1.62287	1.62464	1.62641	1.62818	1.62995	1.63172	1.63349	1.63526	1.63703	1.6388
1.39	1.6388	1.64057	1.64234	1.64411	1.64588	1.64765	1.64942	1.65119	1.65296	1.65473	1.6565
1.40	1.6565	1.65828	1.66006	1.66184	1.66362	1.66540	1.66718	1.66896	1.67075	1.67252	1.6743
1.41	1.6743	1.67608	1.67786	1.67964	1.68142	1.68320	1.68498	1.68676	1.68854	1.69032	1.6921
1.42	1.6921	1.69389	1.69568	1.69747	1.69926	1.70105	1.70284	1.70463	1.70642	1.70821	1.7100
1.43	1.7100	1.7118	1.7136	1.7154	1.7172	1.7190	1.7208	1.7226	1.7244	1.7262	1.7280
1.44	1.7280	1.7298	1.7316	1.7334	1.7352	1.7370	1.7388	1.7406	1.7424	1.7442	1.7460
1.45	1.7460	1.74781	1.74962	1.75143	1.75324	1.75505	1.75686	1.75867	1.76048	1.76229	1.7641
1.46	1.7641	1.76592	1.76774	1.76956	1.77138	1.77320	1.77502	1.77684	1.77866	1.78048	1.7823
1.47	1.7823	1.78412	1.78594	1.78776	1.78958	1.79140	1.79322	1.79504	1.79686	1.79868	1.8005
1.48	1.8005	1.80233	1.80416	1.80599	1.80782	1.80965	1.81148	1.81331	1.81514	1.81697	1.8188
1.49	1.8188	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 6.—*Three-halves powers for numbers from 0 to 12.*

Units. / Hundredths.	0	1	2	3	4	5	6	7	8	9	10	11
0.00	0.0000	1.0000	2.8284	5.1962	8.0000	11.1803	14.6969	18.5203	22.6274	27.0000	31.6228	36.4829
.01	.0010	1.0150	2.8497	5.2222	8.0300	11.2139	14.7337	18.5600	22.6699	27.0450	31.6702	36.5326
.02	.0028	1.0302	2.8710	5.2482	8.0601	11.2475	14.7705	18.5997	22.7123	27.0890	31.7177	36.5824
.03	.0052	1.0453	2.8923	5.2743	8.0902	11.2811	14.8073	18.6394	22.7548	27.1351	31.7652	36.6322
.04	.0080	1.0606	2.9137	5.3004	8.1203	11.3148	14.8442	18.6792	22.7973	27.1802	31.8127	36.6820
.05	.0112	1.0759	2.9352	5.3266	8.1505	11.3485	14.8810	18.7190	22.8399	27.2253	31.8602	36.7319
.06	.0147	1.0913	2.9567	5.3528	8.1807	11.3822	14.9179	18.7589	22.8825	27.2705	31.9078	36.7818
.07	.0185	1.1068	2.9782	5.3791	8.2109	11.4160	14.9549	18.7988	22.9251	27.3156	31.9554	36.8317
.08	.0226	1.1224	2.9998	5.4054	8.2412	11.4497	14.9919	18.8387	22.9677	27.3608	32.0030	36.8816
.09	.0270	1.1380	3.0215	5.4317	8.2715	11.4836	15.0289	18.8786	23.0103	27.4060	32.0506	36.9315
0.10	0.0316	1.1537	3.0432	5.4581	8.3019	11.5174	15.0659	18.9185	23.0530	27.4512	32.0983	36.9815
.11	.0365	1.1695	3.0650	5.4845	8.3323	11.5513	15.1030	18.9585	23.0957	27.4965	32.1460	37.0315
.12	.0416	1.1853	3.0868	5.5110	8.3627	11.5852	15.1400	18.9985	23.1384	27.5418	32.1937	37.0815
.13	.0469	1.2012	3.1086	5.5375	8.3932	11.6192	15.1772	19.0386	23.1812	27.5871	32.2414	37.1315
.14	.0524	1.2172	3.1306	5.5641	8.4237	11.6532	15.2143	19.0786	23.2240	27.6324	32.2892	37.1816
.15	.0581	1.2332	3.1525	5.5907	8.4542	11.6872	15.2515	19.1187	23.2668	27.6778	32.3370	37.2317
.16	.0640	1.2494	3.1745	5.6173	8.4848	11.7213	15.2887	19.1589	23.3096	27.7232	32.3848	37.2817
.17	.0701	1.2656	3.1966	5.6440	8.5154	11.7554	15.3260	19.1990	23.3525	27.7686	32.4326	37.3319
.18	.0764	1.2818	3.2187	5.6708	8.5460	11.7895	15.3632	19.2392	23.3954	27.8140	32.4804	37.3820
.19	.0828	1.2981	3.2409	5.6975	8.5767	11.8236	15.4005	19.2794	23.4383	27.8595	32.5283	37.4322

TABLE 6.—*Three-halves powers for numbers from 0 to 12*—Continued.

Units. / Hundredths.	0	1	2	3	4	5	6	7	8	9	10	11
0.20	0.0894	1.3145	3.2631	5.7243	8.6074	11.8578	15.4379	19.3196	23.4812	27.9050	32.5762	37.4824
.21	.0962	1.3310	3.2854	5.7512	8.6382	11.8920	15.4752	19.3599	23.5242	27.9514	32.6241	37.5326
.22	.1032	1.3475	3.3077	5.7781	8.6690	11.9263	15.5126	19.4002	23.5672	27.9960	32.6720	37.5828
.23	.1103	1.3641	3.3301	5.8050	8.6998	11.9606	15.5501	19.4405	23.6102	28.0416	32.7200	37.6331
.24	.1176	1.3808	3.3525	5.8320	8.7307	11.9949	15.5866	19.4808	23.6533	28.0872	32.7680	37.6833
.25	.1250	1.3975	3.3750	5.8590	8.7616	12.0293	15.6250	19.5212	23.6963	28.1328	32.8160	37.7336
.26	.1326	1.4144	3.3975	5.8861	8.7925	12.0636	15.6616	19.5576	23.7394	28.1784	32.8640	37.7840
.27	.1403	1.4312	3.4201	5.9132	8.8235	12.0981	15.7001	19.6021	23.7825	28.2241	32.9121	37.8343
.28	.1482	1.4482	3.4427	5.9403	8.8545	12.1325	15.7376	19.6425	23.8257	28.2698	32.9600	37.8847
.29	.1562	1.4652	3.4654	5.9675	8.8856	12.1670	15.7752	19.6830	23.8689	28.3155	33.0083	37.9351
0.30	0.1643	1.4822	3.4881	5.9947	8.9167	12.2015	15.8129	19.7235	23.9121	28.3612	33.0564	37.9855
.31	.1726	1.4994	3.5109	6.0220	8.9478	12.2361	15.8505	19.7641	23.9553	28.4069	33.1046	38.0359
.32	.1810	1.5166	3.5337	6.0493	8.9790	12.2706	15.8882	19.8046	23.9986	28.4527	33.1527	38.0864
.33	.1896	1.5338	3.5566	6.0767	9.0102	12.3053	15.9260	19.8452	24.0418	28.4985	33.2009	38.1369
.34	.1983	1.5512	3.5796	6.1041	9.0414	12.3399	15.9637	19.8858	24.0851	28.5444	33.2492	38.1874
.35	.2071	1.5686	3.6025	6.1315	9.0726	12.3746	16.0015	19.9265	24.1285	28.5902	33.2974	38.2379
.36	.2160	1.5860	3.6255	6.1590	9.1040	12.4093	16.0393	19.9672	24.1718	28.6361	33.3457	38.2884
.37	.2251	1.6035	3.6486	6.1865	9.1353	12.4440	16.0772	20.0079	24.2152	28.6820	33.3940	38.3390
.38	.2342	1.6211	3.6717	6.2141	9.1667	12.4788	16.1150	20.0486	24.2586	28.7279	33.4423	38.3896
.39	.2436	1.6388	3.6949	6.2417	9.1981	12.5136	16.1529	20.0894	24.3021	28.7739	33.4906	38.4402
0.40	0.2530	1.6565	3.7181	6.2693	9.2295	12.5485	16.1909	20.1302	24.3455	28.8199	33.5390	38.4908
.41	.2625	1.6743	3.7413	6.2970	9.2610	12.5833	16.2288	20.1710	24.3890	28.8659	33.5874	38.5415
.42	.2722	1.6921	3.7646	6.3247	9.2925	12.6182	16.2668	20.2118	24.4325	28.9119	33.6358	38.5922
.43	.2820	1.7100	3.7880	6.3525	9.3241	12.6532	16.3048	20.2527	24.4761	28.9579	33.6842	38.6429
.44	.2919	1.7280	3.8114	6.3803	9.3557	12.6882	16.3429	20.2936	24.5196	29.0040	33.7327	38.6936
.45	.3019	1.7460	3.8349	6.4081	9.3873	12.7232	16.3810	20.3345	24.5632	29.0501	33.7811	38.7443
.46	.3120	1.7641	3.8584	6.4360	9.4189	12.7582	16.4191	20.3755	24.6068	29.0962	33.8297	38.7951
.47	.3222	1.7823	3.8819	6.4639	9.4506	12.7933	16.4572	20.4165	24.6505	29.1424	33.8782	38.8459
.48	.3325	1.8005	3.9055	6.4919	9.4824	12.8284	16.4954	20.4575	24.6941	29.1885	33.9267	38.8967
.49	.3430	1.8188	3.9292	6.5199	9.5141	12.8635	16.5336	20.4985	24.7378	29.2347	33.9753	38.9475
0.50	0.3536	1.8371	3.9529	6.5479	9.5459	12.8986	16.5718	20.5396	24.7815	29.2810	34.0239	38.9984
.51	.3642	1.8555	3.9766	6.5760	9.5778	12.9338	16.6101	20.5807	24.8253	29.3272	34.0725	39.0493
.52	.3750	1.8740	4.0004	6.6041	9.6097	12.9691	16.6484	20.6218	24.8691	29.3735	34.1211	39.1002
.53	.3858	1.8925	4.0242	6.6323	9.6416	13.0043	16.6867	20.6630	24.9129	29.4198	34.1698	39.1511
.54	.3968	1.9111	4.0481	6.6605	9.6735	13.0396	16.7250	20.7041	24.9567	29.4661	34.2185	39.2020
.55	.4079	1.9297	4.0720	6.6887	9.7055	13.0749	16.7634	20.7453	25.0005	29.5124	34.2672	39.2530
.56	.4191	1.9484	4.0960	6.7170	9.7375	13.1103	16.8018	20.7866	25.0444	29.5588	34.3159	39.3040
.57	.4303	1.9672	4.1200	6.7453	9.7695	13.1457	16.8402	20.8278	25.0883	29.6052	34.3647	39.3550
.58	.4417	1.9860	4.1441	6.7737	9.8016	13.1811	16.8787	20.8691	25.1322	29.6516	34.4135	39.4060
.59	.4532	2.0049	4.1682	6.8021	9.8337	13.2165	16.9172	20.9104	25.1762	29.6980	34.4623	39.4571
0.60	0.4648	2.0238	4.1924	6.8305	9.8659	13.2520	16.9557	20.9518	25.2202	29.7445	34.5111	39.5082
.61	.4764	2.0429	4.2166	6.8590	9.8981	13.2875	16.9943	20.9931	25.2642	29.7910	34.5599	39.5593
.62	.4882	2.0619	4.2408	6.8875	9.9303	13.3231	17.0328	21.0345	25.3082	29.8375	34.6088	39.6104
.63	.5000	2.0810	4.2651	6.9161	9.9626	13.3587	17.0714	21.0759	25.3522	29.8841	34.6577	39.6615
.64	.5120	2.1002	4.2895	6.9447	9.9949	13.3943	17.1101	21.1174	25.3963	29.9306	34.7066	39.7127
.65	.5240	2.1195	4.3139	6.9733	10.0272	13.4299	17.1488	21.1589	25.4404	29.9772	34.7557	39.7639
.66	.5362	2.1388	4.3383	7.0020	10.0596	13.4656	17.1874	21.2004	25.4845	30.0238	34.8045	39.8151
.67	.5484	2.1581	4.3628	7.0307	10.0920	13.5013	17.2172	21.2419	25.5287	30.0704	34.8535	39.8663
.68	.5607	2.1775	4.3874	7.0595	10.1244	13.5370	17.2649	21.2834	25.5729	30.1171	34.9025	39.9176
.69	.5732	2.1970	4.4119	7.0883	10.1569	13.5728	17.3037	21.3250	25.6171	30.1638	34.9516	39.9689

TABLE 6.—*Three-halves powers for numbers from 0 to 12*—Continued.

Units / Hundredths	0	1	2	3	4	5	6	7	8	9	10	11
0.70	0.5857	2.2165	4.4366	7.1171	10.1894	13.6086	17.3425	21.3666	25.6613	30.2105	35.0006	40.0202
.71	.5983	2.2361	4.4612	7.1460	10.2214	13.6444	17.3814	21.4083	25.7056	30.2572	35.0497	40.0715
.72	.6109	2.2558	4.4859	7.1749	10.2545	13.6803	17.4202	21.4499	25.7499	30.3040	35.0988	40.1228
.73	.6237	2.2755	4.5107	7.2038	10.2871	13.7161	17.4591	21.4916	25.7942	30.3507	35.1479	40.1742
.74	.6366	2.2952	4.5355	7.2328	10.3197	13.7521	17.4981	21.5333	25.8395	30.3975	35.1971	40.2256
.75	.6495	2.3150	4.5604	7.2618	10.3524	13.7880	17.5370	21.5751	25.8828	30.4444	35.2462	40.2770
.76	.6626	2.3349	4.5853	7.2909	10.3851	13.8240	17.5760	21.6169	25.9272	30.4912	35.2954	40.3284
.77	.6757	2.3548	4.6102	7.3200	10.4178	13.8600	17.6150	21.6587	25.9716	30.5381	35.3446	40.3798
.78	.6889	2.3748	4.6352	7.3492	10.4506	13.8961	17.6541	21.7005	26.0161	30.5850	35.3939	40.4313
.79	.7022	2.3949	4.6602	7.3783	10.4834	13.9321	17.6931	21.7423	26.0605	30.6319	35.4431	40.4828
0.80	0.7155	2.4150	4.6853	7.4076	10.5163	13.9682	17.7322	21.7842	26.1050	30.6789	35.4924	40.5343
.81	.7290	2.4351	4.7104	7.4368	10.5492	14.0044	17.7714	21.8261	26.1495	30.7258	35.5417	40.5859
.82	.7425	2.4553	4.7356	7.4661	10.5812	14.0406	17.8105	21.8681	26.1941	30.7728	35.5911	40.6374
.83	.7562	2.4756	4.7608	7.4955	10.6150	14.0768	17.8507	21.9100	26.2386	30.8198	35.6404	40.6890
.84	.7699	2.4959	4.7861	7.5248	10.6480	14.1130	17.8889	21.9520	26.2832	30.8669	35.6898	40.7406
.85	.7837	2.5163	4.8114	7.5542	10.6810	14.1493	17.9282	21.9940	26.3278	30.9139	35.7392	40.7922
.86	.7975	2.5367	4.8367	7.5837	10.7141	14.1856	17.9674	22.0361	26.3725	30.9610	35.7886	40.8439
.87	.8115	2.5572	4.8621	7.6132	10.7472	14.2219	18.0067	22.0781	26.4171	31.0081	35.8380	40.8955
.88	.8255	2.5777	4.8875	7.6427	10.7803	14.2582	18.0461	22.1202	26.4618	31.0553	35.8875	40.9472
.89	.8396	2.5983	4.9130	7.6723	10.8134	14.2946	18.0854	22.1623	26.5065	31.1024	35.9370	40.9989
0.90	0.8538	2.6190	4.9385	7.7019	10.8466	14.3311	18.1248	22.2045	26.5523	31.1496	35.9865	41.0507
.91	.8681	2.6397	4.9641	7.7315	10.8798	14.3675	18.1642	22.2467	26.5960	31.1968	36.0360	41.1024
.92	.8824	2.6604	4.9897	7.7702	10.9131	14.4040	18.2037	22.2889	26.6408	31.2441	36.0856	41.1542
.93	.8969	2.6812	5.0154	7.7909	10.9464	14.4405	18.2432	22.3311	26.6856	31.2913	36.1352	41.2060
.94	.9114	2.7021	5.0411	7.8207	10.9797	14.4770	18.2827	22.3733	26.7305	31.3386	36.1848	41.2578
.95	.9259	2.7230	5.0668	7.8505	11.0131	14.5136	18.3222	22.4156	26.7753	31.3850	36.2344	41.3097
.96	.9406	2.7440	5.0926	7.8803	11.0464	14.5502	18.3617	22.4579	26.8202	31.4332	36.2841	41.3615
.97	.9553	2.7650	5.1184	7.9102	11.0799	14.5869	18.4013	22.5003	26.8651	31.4806	36.3337	41.4134
.98	.9702	2.7861	5.1443	7.9401	11.1133	14.6235	18.4409	22.5426	26.9100	31.5280	36.3834	41.4653
.99	.9850	2.8072	5.1702	7.9700	11.1468	14.6602	18.4806	22.5850	26.9550	31.5754	36.4331	41.5173
1.00	1.0000	2.8284	5.1962	8.0000	11.1803	14.6969	18.5203	22.6274	27.0000	31.6228	36.4829	41.5692

The tables of three-halves powers may conveniently be used in conjunction with Crelle's Rechentafeln, or similar tables of the products of pairs of factors. C will usually be constant, or nearly so. Entering Crelle's tables with C or CL as an argument, the discharge corresponding to values of $H^{\frac{3}{2}}$ read from the tables here given may be taken out directly, and usually with sufficient precision at least for 1 foot length of crest, without any arithmetical computation. Table 5 gives $H^{\frac{3}{2}}$ for values of H from zero to 1.5 feet, advancing by thousandths. In Table 6 the increment is 0.1 foot, and the range zero to 12 feet. Should $H^{\frac{3}{2}}$ be required for larger values of H, it may be found from the three-halves power of $\frac{1}{4}H$, by the formula

$$H^{\frac{3}{2}}=8\left(\frac{H}{4}\right)^{\frac{3}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (114)$$

TABLE 7.—FLOW OVER BROAD-CRESTED WEIRS, WITH STABLE NAPPE.

This table gives values of

$$Q = C_1 L H^{\frac{3}{2}},$$

where

$$L = 1$$
$$C_1 = 2.64$$

The derivation of this coefficient is given in connection with discussion of broad-crested weirs (pp. 119–121). It may be applied to broad-crested weirs of any width of cross section exceeding 2 feet within such limiting heads that the nappe does not adhere to the downstream face of the weir for low heads nor tend to become detached with increased head. Under the latter condition the coefficient increases to a limit near the value which applies for a thin-edged weir, a point being finally reached where the nappe breaks entirely free from the broad crest and discharges in the same manner as for a thin-edged weir. The coefficient, 2.64, may often be applied for weirs exceeding 2-feet crest width and for heads from 0.5 foot up to 1.5 or 2 times the breadth of weir crest. If corrections for the velocity of approach are required the Francis correction formula, or its equivalent, should be used.

TABLE 7.—*Weir discharge per foot of crest length.*

[Coefficient C_1=2.64.]

Head H, feet. / Units. Hundredths.	0	1	2	3	4	5	6	7	8	9	10
0.00	0.000	2.64	7.47	13.7	21.1	29.5	38.8	48.9	59.7	71.3	83.5
.01	.003	2.68	7.52	13.8	21.2	29.6	38.9	49.0	59.8	71.4	83.6
.02	.007	2.72	7.58	13.8	21.3	29.7	39.0	49.1	59.9	71.5	83.7
.03	.014	2.76	7.64	13.9	21.4	29.8	39.1	49.2	60.1	71.6	83.9
.04	.021	2.80	7.69	14.0	21.4	29.9	39.2	49.3	60.2	71.7	84.0
.05	.030	2.84	7.75	14.1	21.5	30.0	39.3	49.4	60.3	71.9	84.1
.06	.039	2.88	7.81	14.1	21.6	30.0	39.4	49.5	60.4	72.0	84.2
.07	.049	2.92	7.86	14.2	21.7	30.1	39.5	49.6	60.5	72.1	84.4
.08	.060	2.96	7.92	14.3	21.8	30.2	39.6	49.7	60.6	72.2	84.5
.09	.071	3.00	7.98	14.3	21.8	30.3	39.7	49.8	60.7	72.3	84.6
0.10	0.083	3.04	8.03	14.4	21.9	30.4	39.8	49.9	60.8	72.5	84.7
.11	.096	3.09	8.09	14.5	22.0	30.5	39.9	50.0	61.0	72.6	84.9
.12	.110	3.13	8.15	14.5	22.1	30.6	40.0	50.2	61.1	72.7	85.0
.13	.124	3.17	8.21	14.6	22.2	30.7	40.1	50.3	61.2	72.8	85.1
.14	.138	3.21	8.26	14.7	22.2	30.8	40.2	50.4	61.3	72.9	85.2
.15	.153	3.26	8.32	14.8	22.3	30.8	40.3	50.5	61.4	73.1	85.4
.16	.169	3.30	8.38	14.8	22.4	30.9	40.4	50.6	61.5	73.2	85.5
.17	.185	3.34	8.44	14.9	22.5	31.0	40.5	50.7	61.6	73.3	85.6
.18	.202	3.38	8.50	15.0	22.6	31.1	40.6	50.8	61.8	73.4	85.7
.19	.218	3.43	8.56	15.0	22.6	31.2	40.7	50.9	61.9	73.5	85.9

TABLE 7.—*Weir discharge per foot of crest length*—Continued.

Head *H*, feet. / Units. Hundredths.	0	1	2	3	4	5	6	7	8	9	10
0.20	0.236	3.47	8.61	15.1	22.7	31.3	40.8	51.0	62.0	73.7	86.0
.21	.254	3.51	8.67	15.2	22.8	31.4	40.9	51.1	62.1	73.8	86.1
.22	.272	3.56	8.73	15.2	22.9	31.5	41.0	51.2	62.2	73.9	86.2
.23	.291	3.60	8.79	15.3	23.0	31.6	41.0	51.3	62.3	74.0	86.4
.24	.310	3.64	8.85	15.4	23.0	31.7	41.1	51.4	62.4	74.1	86.5
.25	.330	3.69	8.91	16.5	23.1	31.8	41.2	51.5	62.6	74.3	86.6
.26	.350	3.73	8.97	15.5	23.2	31.8	41.3	51.6	62.7	74.4	86.8
.27	.370	3.78	9.03	15.6	23.3	31.9	41.4	51.7	62.8	74.5	86.9
.28	.391	3.82	9.09	15.7	23.4	32.0	41.5	51.9	62.9	74.6	87.0
.29	.412	3.87	9.15	15.8	23.4	32.1	41.6	52.0	63.0	74.8	87.1
0.30	0.434	3.91	9.21	15.8	23.5	32.2	41.7	52.1	63.1	74.9	87.3
.31	.456	3.96	9.27	15.9	23.6	32.3	41.8	52.2	63.2	75.0	87.4
.32	.478	4.00	9.33	16.0	23.7	32.4	41.9	52.3	63.4	75.1	87.5
.33	.500	4.05	9.39	16.0	23.8	32.5	42.0	52.4	63.5	75.2	87.6
.34	.524	4.10	9.45	16.2	23.9	32.6	42.1	52.5	63.6	75.4	87.8
.35	.547	4.14	9.51	16.2	24.0	32.7	42.2	52.6	63.7	75.5	87.9
.36	.570	4.19	9.57	16.3	24.1	32.8	42.3	52.7	63.8	75.6	88.0
.37	.594	4.23	9.63	16.3	24.1	32.8	42.4	52.8	63.9	75.7	88.2
.38	.618	4.28	9.69	16.4	24.2	32.9	42.5	52.9	64.0	75.8	88.3
.39	.643	4.33	9.75	16.5	24.3	33.0	42.6	53.0	64.2	76.0	88.4
0.40	0.668	4.37	9.82	16.6	24.4	33.1	42.7	53.1	64.3	76.1	88.5
.41	.693	4.42	9.88	16.6	24.4	33.2	42.8	53.2	64.4	76.2	88.7
.42	.719	4.47	9.94	16.7	24.5	33.3	42.9	53.4	64.5	76.3	88.8
.43	.744	4.51	10.0	16.8	24.6	33.4	43.0	53.5	64.6	76.4	88.9
.44	.771	4.56	10.1	16.8	24.7	33.5	43.1	53.6	64.7	76.6	89.0
.45	.797	4.61	10.1	16.9	24.8	33.6	43.2	53.7	64.8	76.7	89.2
.46	.824	4.66	10.2	17.0	24.9	33.7	43.3	53.8	65.0	76.8	89.3
.47	.851	4.70	10.2	17.1	24.9	33.8	43.4	53.9	65.1	76.9	89.4
.48	.878	4.75	10.3	17.1	25.0	33.9	43.6	54.0	65.2	77.0	89.6
.49	.905	4.80	10.4	17.2	25.1	34.0	43.6	54.1	65.3	77.2	89.7
0.50	0.934	4.85	10.4	17.3	25.2	34.0	43.7	54.2	65.4	77.3	89.8
.51	.961	4.90	10.5	17.4	25.3	34.1	43.8	54.3	65.5	77.4	90.0
.52	.990	4.95	10.6	17.4	25.4	34.2	44.0	54.4	65.6	77.5	90.1
.53	1.02	5.00	10.6	17.5	25.4	34.3	44.1	54.6	65.8	77.7	90.2
.54	1.05	5.04	10.7	17.6	25.5	34.4	44.2	54.7	65.9	77.8	90.3
.55	1.08	5.09	10.8	17.7	25.6	34.5	44.3	54.8	66.0	77.9	90.5
.56	1.11	5.14	10.8	17.7	25.7	34.6	44.4	54.9	66.1	78.0	90.6
.57	1.14	5.19	10.9	17.8	25.8	34.7	44.5	55.0	66.2	78.2	90.7
.58	1.17	5.24	10.9	17.9	25.9	34.8	44.6	55.1	66.3	78.3	90.8
.59	1.20	5.29	11.0	18.0	26.0	34.9	44.7	55.2	66.5	78.4	91.0
0.60	1.23	5.34	11.1	18.0	26.0	35.0	44.8	55.3	66.6	78.5	91.1
.61	1.26	5.39	11.1	18.1	26.1	35.1	44.9	55.4	66.7	78.6	91.2
.62	1.29	5.44	11.2	18.2	26.2	35.2	45.0	55.5	66.8	78.8	91.4
.63	1.32	5.49	11.2	18.2	26.3	35.3	45.1	55.6	66.9	78.9	91.5
.64	1.35	5.54	11.3	18.3	26.4	35.4	45.2	55.7	67.0	79.0	91.6
.65	1.38	5.60	11.4	18.4	26.5	35.4	45.3	55.9	67.2	79.1	91.8
.66	1.42	5.65	11.4	18.5	26.6	35.5	45.4	56.0	67.3	79.3	91.9
.67	1.45	5.70	11.5	18.6	26.6	35.6	45.5	56.1	67.4	79.4	92.0
.68	1.48	5.75	11.6	18.6	26.7	35.7	45.6	56.2	67.5	79.5	92.1
.69	1.51	5.80	11.6	18.7	26.8	35.8	45.7	56.3	67.6	79.6	92.3

TABLE 7.—*Weir discharge per foot of crest length*—Continued.

ead *H*, feet. / Units. Hundredths.	0	1	2	3	4	5	6	7	8	9	10
0.70	1.55	5.85	11.7	18.8	26.9	35.9	45.8	56.4	67.7	79.8	92.4
.71	1.58	5.90	11.8	18.9	27.0	36.0	45.9	56.5	67.9	79.9	92.5
.72	1.61	5.96	11.8	18.9	27.1	36.1	46.0	56.6	68.0	80.0	92.7
.73	1.65	6.01	11.9	19.0	27.2	36.2	46.1	56.7	68.1	80.1	92.8
.74	1.68	6.06	12.0	19.1	27.2	36.3	46.2	56.8	68.2	80.2	92.9
.75	1.71	6.11	12.0	19.2	27.3	36.4	46.3	57.0	68.3	80.4	93.0
.76	1.75	6.16	12.1	19.2	27.4	36.5	46.4	57.1	68.4	80.5	93.2
.77	1.78	6.22	12.2	19.3	27.5	36.6	46.5	57.2	68.6	80.6	93.3
.78	1.82	6.27	12.2	19.4	27.6	36.7	46.6	57.3	68.7	80.7	93.4
.79	1.85	6.32	12.3	19.5	27.7	36.8	46.7	57.4	68.8	80.9	93.6
0.80	1.89	6.38	12.4	19.6	27.8	36.9	46.8	57.5	68.9	81.0	93.7
.81	1.92	6.43	12.4	19.6	27.8	37.0	46.9	57.6	69.0	81.1	93.8
.82	1.96	6.48	12.5	19.7	27.9	37.1	47.0	57.7	69.2	81.2	94.0
.83	2.00	6.54	12.6	19.8	28.0	37.2	47.1	57.8	69.3	81.4	94.1
.84	2.03	6.59	12.6	19.9	28.1	37.3	47.2	58.0	69.4	81.5	94.2
.85	2.07	6.64	12.7	19.9	28.2	37.4	47.3	58.1	69.5	81.6	94.4
.86	2.10	6.70	12.8	20.0	28.3	37.4	47.4	58.2	69.6	81.7	94.5
.87	2.14	6.75	12.8	20.1	28.4	37.5	47.5	58.3	69.7	81.9	94.6
.88	2.18	6.80	12.9	20.2	28.5	37.6	47.6	58.4	69.9	82.0	94.7
.89	2.22	6.86	13.0	20.2	28.5	37.7	47.7	58.5	70.0	82.1	94.9
0.90	2.25	6.91	13.0	20.3	28.6	37.8	47.8	58.6	70.1	82.2	95.0
.91	2.29	6.97	13.1	20.4	28.7	37.9	48.0	58.7	70.2	82.4	95.1
.92	2.33	7.02	13.2	20.5	28.8	38.0	48.1	58.8	70.3	82.5	95.3
.93	2.37	7.08	13.2	20.6	28.9	38.1	48.2	59.0	70.4	82.6	95.4
.94	2.41	7.13	13.3	20.6	29.0	38.2	48.3	59.1	70.6	82.7	95.5
.95	2.44	7.19	13.4	20.7	29.1	38.3	48.4	59.2	70.7	82.9	95.6
.96	2.48	7.24	13.4	20.8	29.2	38.4	48.5	59.3	70.8	83.0	95.8
.97	2.52	7.30	13.5	20.9	29.3	38.5	48.6	59.4	70.9	83.1	95.9
.98	2.56	7.36	13.6	21.0	29.3	38.6	48.7	59.5	71.0	83.2	96.0
.99	2.60	7.41	13.6	21.0	29.4	38.7	48.8	59.6	71.2	83.4	96.2
1.00	2.64	7.47	13.7	21.1	29.5	38.8	48.9	59.7	71.3	83.5	96.3

TABLE 8.—BACKWATER CAUSED BY A DAM OR WEIR.

In a channel of uniform depth, width, and slope, let

D=Original uniform depth.
d_2=Depth at the dam or obstruction.
d_1=Depth at a point upstream.
l=Distance upstream to the point d_1.
w=Width of channel.
l_1=Distance upstream to the "hydrostatic limit."
S=Natural uniform slope or inclination of water surface and stream bed, assumed parallel.
g=Acceleration of gravity.
C=Coefficient in the Chezy or slope formula $v=C\sqrt{RS}$,

where R is the hydraulic radius$=\frac{\text{area of section}}{\text{wetted perimeter}}$.

The value of C varies for rivers from about 50 to 140.

The distance upstream from the obstruction at which the depth will be d_1 may be found by the formula

$$l=\frac{d_2-d_1}{S}+D\left(\frac{1}{S}-\frac{C^2}{g}\right)\left[F_1-F_2\right] \quad . \quad . \quad . \quad (115)$$

F is a function of $\frac{d}{D}$, whose value can be expressed mathematically only as a transcendental equation. The numerical values of this function are given in Table 8. F_1 will be found opposite the argument $\frac{D}{d_1}$, and F_2 opposite $\frac{D}{d_2}$.

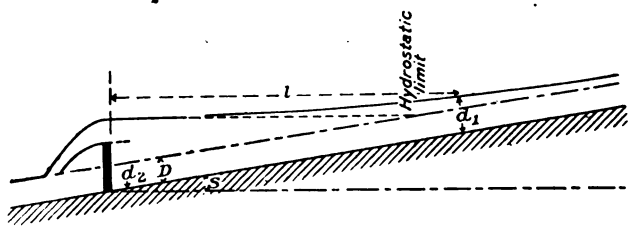


FIG. 15.—Concave backwater surface.

The inverse problem of finding the depth at any given distance l upstream can be solved only by successive trials.

Using the above equation, a series of values of d_1 may be determined giving in tabular form the corresponding values of l. From this data the form of the surface curve may be graphically shown or the depth of back piling at any point may be interpolated.

If $D=5$, $d_2=10$, $C=75$, $S=0.0001$, $\frac{D}{d_2}=0.5$, and $F_2=0.1318$,

$$D\left(\frac{1}{S}-\frac{C^2}{g}\right)=5\left(10000-\frac{75^2}{32.16}\right)=49625.$$

Column (2) in the following table gives the values of l for various values of d_1 computed by means of formula (115).

Form of backwater curve above a dam.

d	l	δ	$d_1-\delta$
Depth, feet (1).	Distance from dam to depth d_1, feet (2).	Hydrostatic depth at distance l, feet (3).	Depth of "back piling," feet (4).
9	11,687	8.83	.17
8	24,277	7.57	.43
7	38,526	6.15	.85
6.5	47,024	5.30	1.20
6.4	48,798	5.13	1.27
6.3	50,796	[a] 5.00	1.30
6.2	52,813	[a] 5.00	1.20
6.1	55,010	[a] 5.00	1.10
6	57,240	[a] 5.00	1.00
5.5	67,252	[a] 5.00	.50
5.3	82,940	[a] 5.00	.30
5.1	101,255	[a] 5.00	.10

[a] Above hydrostatic limit.

If the pond formed by the dam were level, the *hydrostatic depth* δ at any distance upstream would be

$$\delta = d_2 - l \sin S \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (116)$$

Column (3) in the above table shows this factor for the several values of l. The true "back piling" or rise due to the *surface curvature* is expressed by the difference $d_1-\delta$, as given in column (4).

This quantity has a maximum value at the *hydrostatic limit*, or terminus of the level pond, where $\delta = D$.

Its location is such that if l_1 is the distance upstream from the dam

$$l_1 = \frac{d_2 - D}{\sin S} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (117)$$

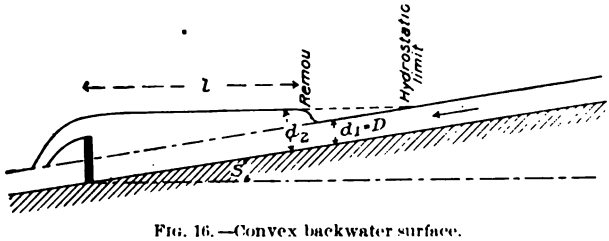


FIG. 16.—Convex backwater surface.

In the example given the hydrostatic limit occurs at a distance l_1=50,000 feet above the dam, at which point the maximum back piling of about 1.31 feet occurs.

Above the hydrostatic limit the depth of back piling is $d_1 - D$.

When $$S \geqq \frac{g}{C^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (118)$$

the pond surface will not be concave, but a *remou* or hydraulic jump will occur, having a height

$$d_2 = 2\sqrt{d_1 \frac{v_1^2}{2g}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (119)$$

where v_1 is the mean velocity corresponding to d_1. To find the distance upstream to the point where the jump occurs, solve equation (115) for the value of d_2, found by formula (119).

If $S=0.004$ $\quad C=100$ $\quad \frac{g}{C^2}=0.003216.$

If $d_1=5$ $\quad w=100$ $\quad D=5$ $\quad R=\frac{500}{110}=4.55.$

$$v_1=100\sqrt{4.55\frac{4}{1000}}=13.49 \text{ feet per second.}$$

$$d_2=2\sqrt{d_1\frac{v_1^2}{2g}}=2\sqrt{5\frac{185}{64.32}}=7.48.$$

Let the depth at the dam be 10 feet; using d_2 as found above as the terminal depth in formula (115), we obtain

$$l=\frac{10-7.48}{0.004}+5\left(\frac{1}{0.004}-311\right)(F_2-F_1)$$

$$\frac{D}{d_1}=\frac{5}{7.48}=0.669 \qquad \frac{D}{d_2}=0.5$$

$$F_1=0.2578 \qquad F_2=0.1318$$

$$l=630+(250-311)\times 0.126=622.3 \text{ feet.}$$

The hydrostatic limit in this case is

$$l_1=\frac{10-5}{0.004}=1{,}250 \text{ feet.}$$

If the channel above an obstruction consists of successive reaches having different slopes or cross sections, the depth at the head of the first reach or level may be found by the method outlined, and using this as the initial depth d_2, a similar solution may be made for the second and succeeding levels.[a]

[a] Table 8 has been extended from Bresse's original table by interpolation. Demonstrations of the formulas here given may be found in Merriman's or Bovey's Hydraulics. In case of a fall a different function must be employed. Its values will be found in the works mentioned.

TABLE 8.—*Backwater function (F) for a dam or obstruction.*

[In headings are hundredths for values of $\frac{D}{d}$ from zero to 0.29, thousandths for values of $\frac{D}{d}$ 0.899, and ten-thousandths for values of $\frac{D}{d}$ from 0.900 to 0.999.]

0	1	2	3	4	5	6	7	8	9
F	*F*	*F*	*F*	*F*	*F*	*F*	*F*	*F*	*F*
0.0000	0.0001	0.0003	0.0005	0.0009	0.0013	0.0018	0.0026	0.0034	0.0042
.0050	.0061	.0072	.0085	.0098	.0113	.0128	.0045	.0162	.0181
.0201	.0221	.0243	.0266	.0290	.0314	.0340	.0367	.0395	.0425
0.0455	0.0458	0.0461	0.0464	0.0467	0.0471	0.0474	0.0477	0.0480	0.0483
.0486	.0489	.0493	.0496	.0499	.0503	.0506	.0509	.0512	.0516
.0519	.0522	.0526	.0529	.0533	.0536	.0539	.0543	.0546	.0550
.0553	.0556	.0560	.0563	.0567	.0570	.0573	.0577	.0580	.0584
.0587	.0591	.0594	.0598	.0601	.0605	.0609	.0612	.0616	.0619
.0623	.0627	.0630	.0634	.0638	.0642	.0645	.0649	.0653	.0656
.0660	.0664	.0668	.0672	.0676	.0680	.0683	.0687	.0691	.0695
.0699	.0703	.0707	.0711	.0715	.0718	.0722	.0726	.0730	.0734
.0738	.0742	.0746	.0750	.0754	.0758	.0763	.0767	.0771	.0775
.0779	.0783	.0787	.0792	.0796	.0800	.0804	.0808	.0813	.0817
0.0821	0.0825	0.0830	0.0834	0.0839	0.0843	0.0847	0.0852	0.0856	0.0861
.0865	.0869	.0874	.0878	.0883	.0887	.0891	.0896	.0900	.0905
.0909	.0918	.0926	.0935	.0943	.0952	.0961	.0969	.0978	.0986
.0995	.0996	.0997	.0997	.0998	.0999	.1000	.1001	.1001	.1002
.1003	.1008	.1013	.1018	.1023	.1030	.1032	.1037	.1042	.1047
.1052	.1057	.1062	.1067	.1072	.1077	.1082	.1087	.1092	.1097
.1102	.1107	.1112	.1118	.1123	.1128	.1133	.1138	.1144	.1149
.1154	.1159	.1165	.1170	.1175	.1180	.1186	.1191	.1196	.1202
.1207	.1212	.1218	.1224	.1229	.1234	.1240	.1246	.1215	.1256
.1262	.1268	.1273	.1279	.1284	.1290	.1296	.1301	.1307	.1312
0.1318	0.1324	0.1330	0.1335	0.1341	0.1347	0.1353	0.1359	0.1364	0.1370
.1376	.1382	.1388	.1394	.1400	.1406	.1411	.1417	.1423	.1429
.1435	.1441	.1447	.1454	.1460	.1466	.1472	.1478	.1485	.1491
.1497	.1503	.1510	.1516	.1522	.1528	.1535	.1541	.1547	.1554
.1560	.1566	.1573	.1580	.1586	.1592	.1599	.1606	.1612	.1618
.1625	.1632	.1638	.1645	.1652	.1658	.1665	.1672	.1679	.1685
.1692	.1699	.1706	.1713	.1720	.1726	.1733	.1740	.1747	.1754
.1761	.1768	.1775	.1782	.1789	.1796	.1804	.1811	.1818	.1825
.1832	.1839	.1847	.1854	.1861	.1868	.1876	.1883	.1890	.1898
.1905	.1912	.1920	.1928	.1935	.1942	.1950	.1958	.1965	.1972
0.1980	0.1988	0.1996	0.2003	0.2011	0.2019	0.2027	0.2035	0.2042	0.2050
.2058	.2066	.2074	.2082	.2090	.2098	.2106	.2114	.2122	.2130
.2138	.2146	.2155	.2163	.2171	.2180	.2188	.2196	.2204	.2213
.2221	.2230	.2238	.2246	.2255	.2264	.2272	.2280	.2289	.2298
.2306	.2315	.2324	.2333	.2342	.2350	.2359	.2368	.2377	.2386
.2395	.2404	.2413	.2422	.2431	.2440	.2450	.2459	.2468	.2477
.2486	.2495	.2505	.2514	.2524	.2533	.2542	.2552	.2561	.2571
.2580	.2589	.2597	.2606	.2615	.2624	.2632	.2641	.2650	.2658
.2667	.2678	.2689	.2700	.2711	.2722	.2734	.2745	.2756	.2767
.2778	.2788	.2799	.2810	.2820	.2830	.2841	.2852	.2862	.2872

TABLE 8.—*Backwater function (F) for a dam or obstruction*—Continued.

[The column headings are hundredths for values of $\frac{D}{d}$ from zero to 0.29, thousandths for values of from 0.30 to 0.899, and ten-thousandths for values of $\frac{D}{d}$ from 0.900 to 0.999.]

$\frac{D}{d}$	0	1	2	3	4	5	6	7	8	9
	F	*F*	*F*	*F*	*F*	*F*	*F*	*F*	*F*	*F*
0.70	0.2883	0.2894	0.2905	0.2915	0.2926	0.2937	0.2948	0.2959	0.2969	0.2980
.71	.2991	.3002	.3013	.3025	.3036	.3047	.3058	.3070	.3081	.3093
.72	.3104	.3116	.3127	.3139	.3150	.3162	.3174	.3186	.3197	.3209
.73	.3221	.3233	.3245	.3258	.3270	.3282	.3294	.3306	.3319	.3331
.74	.3343	.3356	.3368	.3381	.3393	.3406	.3419	.3432	.3444	.3457
.75	.3470	.3483	.3496	.3510	.3523	.3536	.3549	.3563	.3576	.3590
.76	.3603	.3617	.3630	.3644	.3657	.3671	.3685	.3699	.3713	.3727
.77	.3741	.3755	.3770	.3784	.3799	.3813	.3828	.3842	.3857	.3871
.78	.3886	.3901	.3916	.3932	.3947	.3962	.3977	.3993	.4008	.4024
.79	.4039	.4055	.4070	.4086	.4101	.4117	.4133	.4149	.4166	.4182
0.80	0.4198	0.4215	0.4231	0.4248	0.4264	0.4281	0.4298	0.4315	0.4333	0.4350
.81	.4367	.4384	.4402	.4419	.4437	.4454	.4472	.4490	.4508	.4526
.82	.4544	.4563	.4581	.4600	.4618	.4637	.4656	.4675	.4695	.4714
.83	.4733	.4753	.4772	.4792	.4811	.4831	.4851	.4871	.4892	.4912
.84	.4932	.4953	.4974	.4995	.5016	.5037	.5059	.5081	.5102	.5124
.85	.5146	.5168	.5191	.5213	.5236	.5258	.5281	.5304	.5328	.5351
.86	.5374	.5398	.5422	.5446	.5470	.5494	.5519	.5544	.5569	.5594
.87	.5619	.5645	.5671	.5697	.5723	.5749	.5776	.5803	.5830	.5857
.88	.5884	.5912	.5940	.5969	.5997	.6025	.6055	.6084	.6114	.6143
.89	.6173	.6204	.6235	.6265	.6296	.6327	.6359	.6392	.6424	.6457
0.900	0.6489	0.6492	0.6496	0.6499	.6502	0.6506	0.6509	0.6512	0.6515	0.6519
.901	.6522	.6525	.6529	.6532	.6536	.6539	.6542	.6546	.6549	.6553
.902	.6556	.6559	.6563	.6566	.6570	.6573	.6576	.6580	.6583	.6587
.903	.6590	.6594	.6597	.6600	.6604	.6608	.6611	.6614	.6618	.6622
.904	.6625	.6629	.6632	.6636	.6639	.6642	.6646	.6650	.6653	.6656
.905	.6660	.6664	.6667	.6670	.6674	.6678	.6681	.6684	.6688	.6692
.906	.6695	.6698	.6702	.6706	.6709	.6712	.6716	.6720	.6723	.6726
.907	.6730	.6734	.6737	.6741	.6744	.6748	.6752	.6755	.6759	.6762
.908	.6766	.6770	.6773	.6777	.6780	.6784	.6788	.6791	.6795	.6798
.909	.6802	.6806	.6809	.6813	.6817	.6820	.6824	.6828	.6832	.6835
0.910	0.6839	0.6843	0.6846	0.6850	0.6854	0.6858	0.6861	0.6865	0.6869	0.6872
.911	.6876	.6880	.6884	.6887	.6891	.6895	.6899	.6903	.6906	.6910
.912	.6914	.6918	.6922	.6925	.6929	.6933	.6937	.6941	.6944	.6948
.913	.6952	.6956	.6960	.6963	.6967	.6971	.6975	.6979	.6982	.6986
.914	.6990	.6994	.6998	.7002	.7006	.7010	.7013	.7017	.7021	.7025
.915	.7029	.7033	.7037	.7041	.7045	.7049	.7053	.7057	.7061	.7065
.916	.7069	.7073	.7077	.7081	.7085	.7089	.7093	.7097	.7101	.7105
.917	.7109	.7113	.7117	.7121	.7125	.7129	.7133	.7137	.7141	.7145
.918	.7149	.7153	.7157	.7161	.7165	.7170	.7174	.7178	.7182	.7186
.919	.7190	.7194	.7198	.7202	.7206	.7210	.7215	.7219	.7223	.7227
0.920	0.7231	0.7235	0.7239	0.7244	0.7248	0.7252	0.7256	0.7260	0.7265	0.7269
.921	.7273	.7277	.7281	.7286	.7290	.7294	.7298	.7302	.7307	.7311
.922	.7315	.7319	.7324	.7328	.7332	.7336	.7341	.7345	.7349	.7354
.923	.7358	.7362	.7367	.7371	.7375	.7380	.7384	.7388	.7392	.7397
.924	.7401	.7405	.7410	.7414	.7419	.7423	.7427	.7432	.7436	.7441
.925	.7445	.7450	.7454	.7458	.7463	.7468	.7472	.7476	.7481	.7486
.926	.7490	.7494	.7499	.7504	.7508	.7512	.7517	.7522	.7526	.7530
.927	.7535	.7540	.7544	.7549	.7553	.7558	.7563	.7567	.7572	.7576
.928	.7581	.7586	.7590	.7595	.7600	.7604	.7609	.7614	.7619	.7623
.929	.7628	.7633	.7637	.7642	.7647	.7652	.7656	.7661	.7666	.7670

TABLE 8.—*Backwater function (F) for a dam or obstruction*—Continued.

[column headings are hundredths for values of $\frac{D}{d}$ from zero to 0.29, thousandths for values of $\frac{D}{d}$ from 0.30 to 0.899, and ten-thousandths for values of $\frac{D}{d}$ from 0.900 to 0.999.]

$\frac{D}{d}$	0	1	2	3	4	5	6	7	8	9
	F	*F*	*F*	*F*	*F*	*F*	*F*	*F*	*F*	*F*
0.930	0.7675	0.7680	0.7685	0.7689	0.7694	0.7699	0.7704	0.7709	0.7713	0.7718
.931	.7723	.7728	.7724	.7738	.7743	.7748	.7752	.7757	.7762	.7767
.932	.7772	.7777	.7782	.7787	.7792	.7796	.7801	.7806	.7811	.7816
.933	.7821	.7826	.7831	.7836	.7841	.7846	.7851	.7856	.7861	.7866
.934	.7871	.7876	.7881	.7886	.7891	.7896	.7902	.7907	.7912	.7917
.935	.7922	.7927	.7932	.7937	.7942	.7948	.7953	.7958	.7963	.7968
.936	.7973	.7978	.7984	.7989	.7994	.8000	.8005	.8010	.8015	.8021
.937	.8026	.8031	.8037	.8042	.8047	.8052	.8058	.8063	.8068	.8074
.938	.8079	.8084	.8090	.8095	.8101	.8106	.8111	.8117	.8122	.8128
.939	.8133	.8138	.8144	.8150	.8155	.8160	.8166	.8172	.8177	.8182
0.940	0.8188	0.8194	0.8199	0.8205	0.8210	0.8216	0.8222	0.8227	0.8233	0.8238
.941	.8244	.8250	.8256	.8262	.8268	.8274	.8280	.8286	.8292	.8298
.942	.8301	.8307	.8313	.8318	.8324	.8330	.8336	.8342	.8347	.8353
.943	.8359	.8365	.8371	.8377	.8383	.8388	.8394	.8400	.8406	.8412
.944	.8418	.8424	.8430	.8436	.8442	.8448	.8454	.8460	.8166	.8472
.945	.8478	.8484	.8490	.8496	.8502	.8508	.8515	.8521	.8527	.8533
.946	.8539	.8545	.8552	.8558	.8564	.8570	.8577	.8583	.8589	.8596
.947	.8602	.8608	.8615	.8621	.8627	.8634	.8640	.8646	.8652	.8659
.948	.8665	.8672	.8678	.8684	.8691	.8698	.8704	.8710	.8717	.8724
.949	.8730	.8736	.8743	.8750	.8756	.8762	.8769	.8776	.8782	.8788
0.950	0.8795	0.8802	0.8809	.8815	0.8822	0.8829	0.8836	0.8843	0.8849	0.8856
.951	.8863	.8870	.8877	.8883	.8890	.8897	.8904	.8911	.8917	.8924
.952	.8931	.8938	.8945	.8952	.8959	.8966	.8974	.8981	.8988	.8995
.953	.9002	.9009	.9016	.9023	.9030	.9038	.9045	.9052	.9059	.9066
.954	.9073	.9080	.9088	.9095	.9103	.9110	.9117	.9125	.9132	.9140
.955	.9147	.9154	.9162	.9169	.9177	.9184	.9191	.9199	.9206	.9214
.956	.9221	.9229	.9236	.9244	.9252	.9260	.9267	.9275	.9283	.9290
.957	.9298	.9306	.9314	.9321	.9329	.9337	.9345	.9353	.9360	.9368
.958	.9376	.9384	.9392	.9400	.9408	.9416	.9425	.9433	.9441	.9449
.959	.9457	.9465	.9473	.9482	.9490	.9498	.9506	.9514	.9523	.9531
0.960	0.9539	0.9548	0.9556	0.9564	0.9573	0.9582	0.9590	0.9598	0.9607	0.9616
.961	.9624	.9632	.9641	.9650	.9658	.9666	.9675	.9684	.9692	.9700
.962	.9709	.9718	.9727	.9736	.9745	.9754	.9763	.9772	.9781	.9790
.963	.9799	.9808	.9817	.9826	.9835	.9844	.9854	.9863	.9872	.9881
.964	.9890	.9899	.9909	.9918	.9928	.9937	.9947	.9956	.9966	.9975
.965	.9985	.9994	1.0004	1.0013	1.0023	1.0032	1.0042	1.0051	1.0061	1.0070
.966	1.0080	1.0090	1.0100	1.0110	1.0120	1.0130	1.0140	1.0150	1.0160	1.0170
.967	1.0181	1.0191	1.0201	1.0211	1.0221	1.0231	1.0241	1.0251	1.0261	1.0271
.968	1.0282	1.0292	1.0303	1.0314	1.0324	1.0335	1.0346	1.0356	1.0367	1.0378
.969	1.0389	1.0399	1.0410	1.0421	1.0432	1.0443	1.0453	1.0464	1.0475	1.0486
0.970	1.0497	1.0508	1.0519	1.0530	1.0542	1.0553	1.0565	1.0576	1.0587	1.0598
.971	1.0610	1.0622	1.0633	1.0645	1.0657	1.0668	1.0680	1.0692	1.0704	1.0715
.972	1.0727	1.0739	1.0751	1.0763	1.0775	1.0788	1.0800	1.0812	1.0824	1.0836
.973	1.0848	1.0861	1.0873	1.0886	1.0898	1.0911	1.0924	1.0936	1.0949	1.0961
.974	1.0974	1.0987	1.1000	1.1013	1.1026	1.1040	1.1053	1.1066	1.1079	1.1092
.975	1.1105	1.1119	1.1132	1.1146	1.1159	1.1173	1.1187	1.1200	1.1214	1.1227
.976	1.1241	1.1255	1.1269	1.1284	1.1298	1.1312	1.1326	1.1340	1.1355	1.1369
.977	1.1383	1.1398	1.1413	1.1427	1.1442	1.1457	1.1472	1.1487	1.1501	1.1516
.978	1.1531	1.1546	1.1562	1.1578	1.1593	1.1608	1.1624	1.1640	1.1655	1.1670
.979	1.1686	1.1702	1.1718	1.1735	1.1751	1.1767	1.1783	1.1799	1.1816	1.1832

TABLE 8.—*Backwater function* (F) *for a dam or obstruction*—Continued.

[The column headings are hundredths for values of $\frac{D}{d}$ from zero to 0.29, thousandths for values of $\frac{D}{d}$ from 0.30 to 0.899, and ten-thousandths for values of $\frac{D}{d}$ from 0.900 to 0.999.]

$\frac{D}{d}$	0	1	2	3	4	5	6	7	8	9
	F	*F*	*F*	*F*	*F*	*F*	*F*	*F*	*F*	*F*
0.980	1.1848	1.1865	1.1882	1.1899	1.1916	1.1934	1.1951	1.1968	1.1985	1.2002
.981	1.2019	1.2037	1.2055	1.2073	1.2091	1.2109	1.2127	1.2145	1.2163	1.2181
.982	1.2199	1.2218	1.2237	1.2256	1.2275	1.2294	1.2314	1.2333	1.2352	1.2371
.983	1.2390	1.2410	1.2430	1.2451	1.2471	1.2491	1.2511	1.2531	1.2552	1.2572
.984	1.2592	1.2614	1.2635	1.2656	1.2678	1.2700	1.2721	1.2742	1.2764	1.2786
.985	1.2807	1.2830	1.2853	1.2876	1.2899	1.2922	1.2945	1.2968	1.2991	1.3014
.986	1.3037	1.3062	1.3086	1.3111	1.3136	1.3160	1.3185	1.3210	1.3235	1.3259
.987	1.3284	1.3311	1.3337	1.3364	1.3391	1.3418	1.3444	1.3471	1.3498	1.3524
.988	1.3551	1.3580	1.3609	1.3638	1.3667	1.3696	1.3725	1.3754	1.3782	1.3812
.989	1.3841	1.3873	1.3905	1.3936	1.3968	1.4000	1.4032	1.4064	1.4095	1.4127
0.990	1.4159	1.4194	1.4229	1.4264	1.4299	1.4334	1.4370	1.4405	1.4440	1.4475
.991	1.4510	1.4549	1.4588	1.4628	1.4667	1.4706	1.4745	1.4784	1.4824	1.4863
.992	1.4902	1.4947	1.4991	1.5036	1.5080	1.5125	1.5170	1.5214	1.5259	1.5303
.993	1.5348	1.5399	1.5451	1.5502	1.5553	1.5604	1.5656	1.5707	1.5758	1.5810
.994	1.5861	1.5922	1.5983	1.6043	1.6104	1.6165	1.6226	1.6287	1.6347	1.6408
.995	1.6469	1.6543	1.6618	1.6692	1.6767	1.6841	1.6915	1.6990	1.7064	1.7139
.996	1.7213	1.7309	1.7405	1.7501	1.7597	1.7692	1.7788	1.7884	1.7980	1.8076
.997	1.8172	1.8307	1.8442	1.8577	1.8712	1.8848	1.8982	1.9118	1.9253	1.9388
.998	1.9523	1.9754	1.9985	2.0216	2.0447	2.0678	2.0910	2.1141	2.1378	2.1603
.999	2.1834	.....	.....	.....	.....	.....	.....	.....	.....	.....
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3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they may be had at prices slightly above cost.

4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they may be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the sixteenth in Series M, the complete list of which follows. (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper):

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WS 150. Weir experiments, coefficients, and formulas, by R. E. Horton. 1906. 189 pp., 38 pls.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

JANUARY, 1906.

O

Water-Supply and Irrigation Paper No. 151 Series L, Quality of Water, 11

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

FIELD ASSAY OF WATER

BY

MARSHALL O. LEIGHTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., June 9, 1905.

SIR: I transmit herewith a manuscript entitled "Field Assay of 'ater," by Marshall O. Leighton, and request that it be published as ıe of the series of Water-Supply and Irrigation Papers.

In this manuscript are described and discussed the methods which ıve for some time been used with success in connection with the vestigations into the quality of water in various parts of the United tates carried on by the division of hydro-economics. As the meth- ls have proved of value, it is believed that their publication in the ›rm submitted will be of general interest.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

FIELD ASSAY OF WATER

By M. O. Leighton.

INTRODUCTION.

A chemist aims to secure exceeding refinement in analytical methods and results. He seldom considers whether or not a method is sufficiently exact for certain broad purposes. The fact that it is incomplete, approximate, or susceptible of refinement is to him sufficient reason for improving or rejecting it at the first opportunity.

The scrutiny to which chemical methods have been subjected in the endeavor to secure exact results has led in many cases to processes so complicated and expensive that in commercial work the advantages do not compensate for the increased cost and delay which the methods involve. The result has been that the chemical profession distinguishes between two classes of chemical methods which differ in degree of accuracy. The first includes the exact methods, which afford results as nearly perfect as chemical procedure will permit. Such methods are used in all cases where minute differences in analysis would cause errors in interpretation or in subsequent chemical procedure. The second class consists of "commercial methods," so called because the results obtained by them, while departing from the actual truth, are sufficiently accurate to insure the profitable conduct of industrial chemical processes without appreciable error or waste. Methods of the first class are the product of chemistry, while those of the second are used in response to the demands of expediency—they are good enough for the purposes for which they are used.

In no branch of chemistry are approximate results more serviceable than in the analysis of water for hydro-economic surveys, or surveys made to determine the value of water and its applicability for use in domestic supply, boilers, industries, etc. Under the conditions which generally prevail it is necessary to resort to long, tedious, and expensive processes in order to secure a determination of the character and amount of foreign constituents in water. It is the practice in such cases to secure a sample of the water and transport

it to a laboratory, where, after conventional delays, it is passed through the usual course of analysis.

There has in the past been surprisingly little discrimination used with reference to the selection of determinations for specific purposes, and as a general rule the same procedure has usually been followed without regard to the object of the particular investigation. If the purpose of the analysis is to determine the incrusting constituents, the course pursued has been to follow the entire analytical procedure. If, on the other hand, it is desired to determine the amount of organic pollution in a water and show its value for domestic use, the chemist forthwith begins the round of nitrogen determinations, and closes with a statement of the oxygen consumed and the number of bacteria per cubic centimeter. In only a few well-known laboratories has this rule been violated, and such is the conservatism in the chemical profession that it will probably be largely followed in future. Conservatism is the safeguard of science and one of the most commendable qualities of a chemist, but an excess is sometimes almost as bad as a deficiency.

SANITARY ANALYSES.

The requisites to be met by a water in almost every line of special development are broad and flexible. In the sanitary analysis certain results receive certain interpretations, which remain generally unchanged if the results are varied by 1, 2, 3, or sometimes even 10 per cent. A strange feature in connection with sanitary analyses of water is that, in addition to insisting upon superrefinement, many chemists persist in making determinations that are admittedly to no purpose. It is a common thing to see an analyst's report of a water containing the results of determinations of albuminoid and free ammonia, nitrates, and nitrites, accompanied by a footnote stating that these results are unworthy of trust and mean very little, except to verify conclusions made from inspection of the territory from which the water was taken. In case such conclusions do not agree with the analytical evidence, the latter is invariably discredited.

It is to be hoped that some day the great and growing swarm of water analysts will awaken to the fact that sanitary analyses, as generally applied and interpreted, are but a succession of unrelated absurdities. Water experts, who encounter real problems, who must use analytical data as a basis for the design and construction of purification plants, and whose varied experience has taught them that in the United States the waters are as diverse in character as the climates, have learned a few things not taught in text-books nor anticipated in the beautiful theory of the oxidation of organic matter.

The occasional isolated sanitary analysis of water is positively without value. There are throughout the country numerous State, munic-

pal, and private laboratories in which sanitary analyses are carried on. The water analyzed to-day may be from a well, to-morrow from a brook, and the next day from a pond. From the results of a single analysis wise and ponderous verdicts are sent broadcast, and the eager, waiting public is duly impressed. No one understands how singularly misleading a sanitary analysis of water can be until he has examined the results of such analyses of samples taken daily or hourly from the same source; then he sees that in general only a few single analyses in the group contain results which would admit of the interpretation that is finally placed upon the series.

If there is at hand a well-defined problem which involves the consideration of nitrogenous matter and the state in which it appears in water, certain daily nitrogen determinations are of undoubted value; not, however, by reason of the absolute amounts which are revealed in each determination, but by reason of the daily relations and variations which appear in the successive analyses, and upon which interpretations can be placed. This statement, it should be emphasized, refers almost entirely to water slightly or moderately polluted, and does not include sewage. The organic matter normally occurring in a natural water, or what may be more accurately described as a highly dilute sewage, is, after all, practically infinitesimal in amount. The difficulties attendant upon a determination of nitrogen in its various forms and the true interpretation of the results, grow less and less as the amount of organic matter is increased. Yet, even with strong sewages some of the determinations, such as albuminoid ammonia and nitrites, are not usually productive of valuable information.

In an article entitled "The composition of sewage in relation to problems of disposal,"[a] Mr. George W. Fuller discusses in a characteristically clear manner an experiment which illustrates the apparent utility of the albuminoid-ammonia determination, as follows:

[Illustrative of the varying relation of nitrogen in the form of albuminoid ammonia to the total organic nitrogen present in raw sewage, there are given below in a table the results of an experiment made in the Lawrence laboratory and published in the 1894 report of the Massachusetts State board of health, page 461. A bottle of fresh sewage was analyzed just after its collection and again at frequent intervals, allowing the natural decomposition processes to take place at room temperature. In this table it is seen that fresh sewage contains dissolved oxygen, coming, of course, from the water supply which forms the principal portion of the sewage. It also contains nitrogen in the form of nitrates, as well as other salts which are completely oxidized. Through the agency of the bacteria and the oxygen dissolved in the water and yielded by the oxidized salts, the carbon of the organic matter is oxidized and the organic nitrogen uniting with the hydrogen forms free ammonia.

[a] Technology Quarterly, June, 1903, pp. 143–144.

Changes in composition occurring in fresh Lawrence sewage upon standing in a bottle in the laboratory.

[Parts per million.]

Date of examination.		Free ammonia.	Nitrogen as—						Nitrites and nitrates.	Total nitrogen.	Oxygen consumed.		Per cent dissolved oxygen.	Bacteria per cubic centimeter.
			Albuminoid ammonia.			Organic (Kjeldahl).								
Day.	Hour.		Dissolved.	Suspended.	Total.	Dissolved.	Suspended.	Total.			Two minutes.	Five minutes.		
March 11	10.30 a. m.	18.5	5.8	2.1	7.9	31.4	9.1	40.3	3.5	63.2	85.0	132.0	57	1,190,000
March 11	12.30 p. m.	20.6	5.8	2.4	8.2	28.9	11.4	40.3	3.1	63.9	81.0	142.0	60	1,085,000
March 11	3.00 p. m.	21.0	5.8	2.5	8.3	28.9	10.7	39.6	2.9	63.4	85.0	133.0	60	1,505,000
March 11	6.00 p. m.	23.4	5.6	2.7	8.3	27.8	9.9	37.7	2.5	63.6	85.0	133.0	30	1,580,000
March 12	8.00 a. m.	40.7	4.9	3.9	8.8	11.6	12.2	23.8	0.3	64.6	74.0	107.0	0	20,475,000
March 12	12.00 m	41.2	4.9	4.4	9.3	11.6	8.2	19.8	0.2	61.0	69.0	98.0	0	23,100,000
March 12	5.00 p. m.	41.2	4.2	4.2	8.4	11.6	10.1	21.7	0.0	62.7	69.0	98.0	0	20,000,000
March 13	10.30 a. m.	42.0	4.7	3.5	8.2	11.6	8.2	19.8	0.0	61.6	60.0	89.0	0	12,810,000
March 14	10.30 a. m.	41.2	3.3	4.5	7.8	9.4	8.4	17.8	0.0	58.8	55.0	72.0	0	11,285,000
March 15	10.30 a. m.	41.2	3.4	4.3	7.7	9.3	8.3	17.6	0.0	57.6	49.0	66.0	0	6,835,000
March 16	10.30 a. m.	41.2	3.5	4.1	7.6	7.5	8.9	16.4	0.0	57.4	48.0	72.0	0	4,485,000
March 18	10.30 a. m.	42.0	3.0	3.8	6.8	7.4	6.9	14.3	0.0	56.1	51.0	70.0	0	3,480,000
March 19	10.30 a m.	42.8	3.0	3.9	8.9	5.9	7.8	13.7	0.0	56.3	50.0	71.0	0	2,841,000

it is seen from the results in the table, page [12], that the dissolved oxy- l the nitrates gradually disappear, the bacteria for a time increase, the consumed (carbonaceous matter) decreases, the nitrogen as free ammo- reases, and the organic nitrogen (Kjeldahl) decreases. The nitrogen iminoid ammonia, however, remains approximately constant, notwith- g that more than 20 parts of organic nitrogen are changed to free am- and some 5 or 6 parts of free nitrogen escape into the atmosphere.

nitrite determination, which has been regarded by many as the most valuable pollution indicators, fluctuates in a stream ervoir according to the amount of available oxygen rather than nount of organic matter undergoing oxidation. It will rise ll in amount when there is a positive certainty that it can not e to increase or decrease of organic pollution. Nevertheless, an interpretation has been made largely on the evidence pre- by this determination.

far the greater number of sanitary water analyses reported e the determination of oxygen consumed, a test which is dent upon so many features that as a whole the great mass of inations which have been made are valueless for purposes of rison. The following table, compiled by Mr. George W. , shows clearly the relative results of the determinations made ing to different methods. In short, the only practical value of oxygen-consumed" determination is in its application to highly ed waters of the same general character and origin, and then or purposes of comparison between the successive determina- made by absolutely the same method. In other words, it is ally a sewage determination.

imate comparison of average amounts of oxygen consumed by sewage and sewage effluents as shown by different methods.

Method.	Temperature of solution.	Period of contact.	Relative results.
as practiced at Boston and gener- n America.	Boiling	5 minutes	1.00
as practiced at Lawrence, Mass	do	2 minutes	.65
as practiced in Germany	do	10 minutes	1.25
official tests	80° F	3 minutes	.20
	do	15 minutes	.35
	do	4 hours	.60
ate" oxygen consumed	Boiling	do	4.00

INORGANIC ANALYSES.

he determination of inorganic constituents in a water it would no difference, in the decision to accept or reject that water for use, for irrigation, or for manufacturing, if the harmful con- its were contained, for example, in the proportion of 40, 44, grains per gallon. The lines dividing good and bad water for

boiler purposes are very broad. If a water contains a certain amount of incrusting constituents and a method used is inaccurate to a limit of 5, or even 10, per cent, it would not lead to the acceptance of a bad water or the rejection of a good one. The "good" and "bad" provinces are approached too gradually to admit of such consequences.

Another error arises from the conventional methods of expression of results. If the analyst finds that a water contains certain amounts of calcium, magnesium, sodium, and potassium, and certain equivalents of the carbonate, sulphate, and chloride radicals, he unites these substances according to methods which are apparently not uniform and entitled to little scientific justification. It is a well-known fact that if several chemists, each independent of every other, analyze a certain water, there will almost invariably be wide differences in the expression of results.

Dr. F. W. Clarke, chief chemist of the United States Geological Survey, in a recent communication has given an excellent illustration of the various hypothetical combinations which may be made of the results of a single analysis of water. The statements are set forth in the following table. Each series of combinations is based upon a generally accepted hypothesis, and each represents a water that is totally different from the others.

Analysis of water from artesian well at Macomb, Ill.[a]

[Grams per liter.]

Statement in ionic form.		Statement according to hypothetical combinations.				
SiO_2	0.0105	KCl		0.0452	0.0181	0.0211
Al_2O_3	.0013	$NaCl$	0.8968	.8384	.7164	.8172
Fe_2O_3	.0023	$CaCl_2$			.0877	.0292
SO_4	.9991	$MgCl_2$		.0154	.0571	.0242
CO_3	.3953	K_2SO_4	.0528		.0211	.0246
Cl	.5418	Na_2SO_4	.4649	1.4781	1.2495	1.0642
Na	.8086	$CaSO_4$	.5450		.1218	.2223
K	.0237	$MgSO_4$	.3360		.0711	.1357
Ca	.1581	K_2CO_3			.0084	.0028
Mg	.0672	Na_2CO_3	.6983		.2793	.3259
		$CaCO_3$		.3952	.2278	.2076
		$MgCO_3$		.2215	.1355	.1190
		Al_2O_3[b]	.0013	.0013	.0013	.0013
		Fe_2O_3[b]	.0020	.0020	.0020	.0020
		SiO_2[b]	.0105	.0105	.0105	.0105
			3.0076	3.0076	3.0076	3.0076

[a] By George Steiger, laboratory of United States Geological Survey.
[b] Al_2O_3, Fe_2O_3, SiO_2, conventionally regarded as colloidal.

The inorganic constituents of a water should invariably be expressed as positive and negative ions, and if so expressed the result determined according to approximate methods is as valuable as the expression of precisely determined constituents united according to the individual ideas of the analyst.

GENERAL OBSERVATIONS.

A practical disadvantage in chemical water surveys arising from the insistence on refined methods of analysis and lack of discrimination in the choice of specific determinations is the delay which arises in securing valuable information with reference to wide areas. Months and even years have been spent upon water surveys covering only a comparatively small portion of the country. Two examples are here cited.

The most important chemical survey in the United States has been carried on since 1888 by the Commonwealth of Massachusetts. This survey work may safely be taken as the standard in this or any other country. During this period of sixteen years the appropriations for the work have been on an average about $30,000 a year, making a total cost of not far from $480,000. A large part of this sum has been used to pay expenses of experimentation and can not be charged to water survey. The work was confined to Massachusetts.

In the year 1898 the Ohio State board of health commenced an examination of the principal streams of the State, making monthly analyses of samples of water taken from numerous points along the various streams. This work was continued five years before the State was covered, and there resulted merely a large number of periodical analyses in sets of twelve, showing the character of the stream water and its variation according to local conditions.

These two cases are typical. No one would claim that all the results could have been reached by the use of field methods. Undoubtedly a large part of them could have been obtained far more cheaply and quickly, and there would have been no loss to the cause of pure water, nor to science generally, had some of the determinations been omitted.

Among water analysts there seems to be a general tendency to attack every water problem as though the object were to prove its fitness or unfitness for drinking purposes. In many investigations it is well known at the outset that the water can not be used for domestic purposes and the problem is of quite another character. The conventional grind of nitrogen determinations has been made to do service in almost every conceivable water problem. It has been used frequently in investigating pollution problems in which organic matter had absolutely no part. A study of the results obtained in ma

laboratories will show that in the routine work a number of determinations could be omitted without detriment. These facts are mentioned in order to emphasize the point that if care and discrimination were used in the selection of tests the work necessary in carrying on chemical surveys might be decreased and the money available for such work might be distributed over a wider field; results of more immediate use might be secured and the completion of a chemical survey would not be postponed for the benefit of future generations. "Commercial methods" serve useful purposes in manufacturing; the success of enormous industrial plants is dependent upon them, and in water surveys they would at least be businesslike.

It was these considerations, in connection with the knowledge of the vast areas covered by the United States, which led the United States Geological Survey, through its hydro-economic division, to investigate the practicability of employing field methods for the determination of important characteristics of water. It was realized that if there could be provided a few simple tests, the apparatus for which could be taken into the field and used on the spot, large areas might be covered in a short time, and if it were necessary for any reason to make periodical determinations the cost of the work would still be small and the total would not run up into the large sums which have been spent in such investigations. In general, the testimony of a large number of approximate results is far more representative of actual conditions than that of one or two refined analyses.

The idea of testing waters in the field is by no means new. Very successful field tests have been carried on by numerous authorities. Probably one of the most successful systems now in use is that of the Bureau of Soils, Department of Agriculture. Another excellent field outfit for sanitary analysis has been devised and used with satisfaction by Mrs. Ellen H. Richards. Several others are noteworthy. They all involve the use of considerable apparatus and the carrying of standard solutions. Specially equipped wagons are necessary in some cases. In others the variety of determinations is limited or the equipment can not be used in an extensive circuit without renewal of reagents. The difficulty of carrying solutions and complex apparatus into the field is obvious. The ideal equipment is one which can be carried on journeys afoot or on horseback without much fatigue. The sources of useful or desirable water supply are not distributed with reference to the railroad or wagon routes and the field man must often climb mountains or trace obscure trails to accomplish his purpose. The outfit should contain a sufficient supply of reagents to serve for a large number of determinations without renewal. The processes should be rapid and the results fairly accurate and comprehensive. Finally, the equipment should be provided with material for so various a series of determinations that with proper discrim-

on the essential characteristics of a water may be shown, whether purposes be domestic or industrial water supply, irrigation, or other special line of utilization. Volumetric methods requiring se of burettes are objectionable; gravimetric methods are impos- Therefore, in the Survey's study of field methods the whole er developed into a question of choosing the most useful deter- tions and so modifying the volumetric methods that their use d be practicable, while at the same time they would give a degree curacy sufficiently close for all practical purposes.

the methods hereinafter proposed the term "assay" readily itself. There is no attempt at water analysis. The plan contem- s the determination of ingredients which give to water certain known characteristics. The methods and the suggestions with ence to their application are only tentative and will be modified perience may dictate. As they stand they are the result of ded experimentation, and the tests to which they have been put that they are practicable. They have been found to be more y accurate than was at first anticipated, though this fact, it is ved, has not greatly increased their usefulness for the purposes ew. By their use, combined with a fair amount of common , the essential characteristics of waters can be ascertained at expense. In almost every situation in which such determina- are significant they will afford sufficiently satisfactory data. e case of finely balanced considerations of a purely physical, ical, or geologic nature, however, they are practically useless. are intended for practical purposes and have no place in pure ce.

FIELD DETERMINATIONS.

e following determinations are described on subsequent pages:

1. Turbidity.
2. Color.
3. Iron.
4. Chlorine or total chlorides.
5. Total hardness.
6. Alkalinity.
7. Normal carbonates.
8. Bicarbonates.
9. Total sulphates.
10. Calcium.

should be stated at the outset that the successful operation of methods depends, as in all chemical procedure, upon the manner hich they are applied. A failure to insist upon strict compli- with the rules laid down may result in total failure.

SUSPENDED MATTER.

The turbidity of water is that property which is imparted to it by substance carried in suspension. In many parts of the United States waters are often extremely muddy, and when this condition is maintained during long periods it becomes one of the most serious difficulties with which the water-supply engineer has to deal. Turbid water is objectionable for domestic use. In industrial operations, especially in those in which water enters into manufacturing processes, turbidity is a factor which, if not removed, may exert a harmful influence upon the manufactured products. It is also important in connection with irrigation works. One of the serious troubles in Western reservoirs is loss of storage capacity due to silt deposits. In the construction of irrigation canals the amount of turbidity usually carried by the water often determines the grade of the canal. Such canals must have grade sufficient to cause the flowing water to carry along suspended matter and not allow it to settle. If this is not taken into consideration, the maintenance of the irrigation system becomes extremely expensive, and cases have occurred where the canals have been practically filled by the deposits of suspended matter.

The suspended substances causing turbidity are of various characters. They are found often in a flocculent condition, settling readily when the water which carries them becomes quiescent. On the other hand, the turbid matter is often made up of minute particles of clay, so fine that they pass through certain filtering media. In some cases the problem of removing turbidity from the water is so difficult that the process which may be successful is so radical that it will remove also dissolved organic material and even a large number of the bacteria.

METHODS OF DETERMINATION.

There are several methods of estimating the proportion of suspended matter in a water, all but one of which have their particular fields of usefulness. The first is merely a statement of the observer's opinion of the degree of turbidity, such as "very slight," "slight," "distinct," or "decided." Although this method of estimation has no real value, it is used by many water chemists.

The second method is also based upon the appearance of the water, but differs from the first in that a definite and fairly well-fixed basis of comparison is provided. A water containing no suspended matter is practically transparent, but matter in suspension intercepts the rays of transmitted light. An observer can see objects distinctly through a body of clear water, but as the water becomes more and more muddy the objects can be seen less and less distinctly until

they are quite lost to view. Now, it has been found by experiment that there is a fairly definite relation between the proportion of light rays intercepted and the amount of matter in suspension. This relation varies somewhat with the character of the suspended matter and with the size of the particles, but for the purpose to which this method of measurement is applicable the variations do not often seriously affect the interpretations placed upon the results. The details of the method will be explained on later pages under the caption "Turbidity." For the present it will be sufficient to state that it has found its greatest usefulness in connection with the adaptation and operation of water-filtration plants and sewage-disposal works.

The third method of measuring the amount of suspended matter in water consists in separating it from a weighed portion of the fluid by filtration, weighing the filtered water, and stating the difference between the two weights as suspended matter. The form of statement commonly used is parts of suspended matter per million of water, milligrams per liter, or some other comprehensive proportion. This is undoubtedly the best method of determination, as it is relatively accurate and can be used in the study of all water problems. Its practical disadvantage is that the determination requires a large amount of time and can not be economically performed in serial investigations without considerable equipment and tedious labor. It is also true that the processes for which a knowledge of suspended matter is necessary will generally in practical work be as well served by an approximate determination as by a precise one; therefore the cruder methods, based upon photometry, are more often used.

There is, however, no necessarily constant relation between the weight of suspended matter in a given volume of water and the turbidity produced. A certain weight of suspended substance of one kind does not usually produce the same degree of turbidity as a similar weight of another substance. In other words, the turbidity determination takes no account of the character, weight, or volume of the suspended matter. This has been clearly demonstrated by Mr. Robert Spurr Weston in the report on Water-Purification Investigation and on Plans Proposed for Sewerage and Waterworks Systems made to the sewerage and water board of New Orleans, La., pages 27 and 28. To overcome the errors above cited, Mr. Weston has proposed the use of a "turbidity coefficient," as follows:

All optical methods for the determination of turbidity are naturally compared with the gravimetric determination of the suspended matter which produces the turbidity. Equal weights of suspended matter do not necessarily produce the same turbidity. For example, waters which contain suspended silt or sand exhibit less turbidity per unit of suspended matter by weight than do waters containing finely divided clay. Therefore the ratio between silica turbidity,

determined optically, and suspended matter, determined gravimetrically, is most important, as it is an index of the character of the suspended matter producing the turbidity. To express this relation most conveniently, the term "turbidity coefficient" has been adopted.

$$\text{Turbidity coefficient equals } \frac{\text{Suspended matter.}}{\text{Silica turbidity.}}$$

Naturally this coefficient varies with different waters, generally increasing with the size of the particles composing the suspended matter. Thus the samples of unsettled river water have the highest turbidity coefficient, while samples from the effluents of the three-day subsiding basins have the lowest, as the following table will show:

Table of average turbidity coefficients.

	Turbidity coefficient.
Mississippi River water	1.68
Mississippi River water, after 6 hours' subsidence	.90
Mississippi River water, after 12 hours' subsidence	.87
Mississippi River water, after 18 hours' subsidence	.86
Mississippi River water, after 24 hours' subsidence	.85
Mississippi River water, after 48 hours' subsidence	.80
Mississippi River water, after 24 hours' subsidence and coagulation	.60

This table is very easy to understand, since the coarser particles of low turbidity-producing power and somewhat higher specific gravity gradually separate out according to their hydraulic values, the finer particles of high turbidity-producing power and somewhat lower specific gravity remaining longest in suspension.

The idea of Mr. Weston above set forth is an admirable one and should be utilized in connection with all water investigations.

The fourth method of determining suspended matter consists in measuring the cubical contents thereof after sedimentation. This method takes no account of the weight of the substance nor of the turbidity produced by it, and its particular value is confined to those highly turbid waters which it is proposed to conserve in storage reservoirs or to conduct in canals. In the preparation of reservoirs for irrigation and domestic uses in the arid and semiarid regions, one of the most troublesome features is the loss of storage capacity in the reservoir by reason of its filling up with matter deposited from suspension, and indeed it is necessary in the construction of these reservoirs to provide means whereby the silt can be removed at proper intervals. The problem is, therefore, one of cubical contents and the observations are usually made by filling a 100 c. c. graduate with the turbid water, allowing the suspended matter to settle, and reading the depth of the sediment and expressing it in percentage terms.

The results of such observations do not bear any more constant relation to the turbidity produced by the suspended matter than do the determinations of actual weight. An interesting series of observations upon this point has recently been compiled by the Geological

urvey, the water being taken from Gila River at San Carlos, Ariz. his river is probably the muddiest in the United States, and the bservations represent extreme conditions. Turbidity measurements onsume so small an amount of time in comparison with that necessary ı the observation of per cent volume of total solids that an endeavor as made to determine whether or not turbidity measurements pos- ess any constant relation to amount of matter. If such were found be the case the work necessary in preparing plans for storage reser- oirs would be considerably shortened.

Parallel determinations were therefore made of turbidity and per ent volume of sediment upon daily samples taken from Gila River rom July 21 to October 24, 1904, the results of which are set forth in ie following table. It will be noted in this table that the conversion ictor, which should be constant if the hypothesis were correct, varies widely as to indicate unmistakably the entire absence of any con- ant relation between the two sets of observations:

arallel observations of per cent volume of sediment and of turbidity, in terms of parts per million, of silica in water from Gila River at San Carlos, Ariz.

Date.	Per cent sediment volume.	Turbidity (silica parts per million).	Conversion factor.	Date.	Per cent sediment volume.	Turbidity (silica parts per million).	Conversion factor.
ıly 21	12	27,300	2,280	Aug. 12	15	63,936	4,260
22	16.5	37,800	2,290	13	10	57,600	5,760
23	19	43,200	2,280	14	11	33,550	3,050
24	18.5	43,200	2,340	15	17	48,000	2,820
25	21	44,784	2,140	16	18.5	54,000	2,920
26	18	41,568	2,310	17	15	42,000	2,800
27	16	40,572	2,540	18	13	39,000	3,000
28	9	40,800	4,530	19	9	33,000	3,670
29	21	53,000	2,520	20	12	39,000	3,250
30	19	64,000	3,370	21	15.5	36,000	2,320
31	12	64,000	5,330	22	13	36,000	2,770
ıg. 1	13	53,312	4,110	23	10	27,000	2,700
2	22	73,536	3,340	24	13	39,000	3,000
3	20	67,200	3,350	25	8	30,000	3,750
4	19	70,368	3,680	26	9	30,000	3,340
5	15	63,936	4,260	27	8	27,000	3,380
6	15	62,400	4,160	28	8	24,000	3,000
7	14	62,400	4,460	29	8	27,000	3,380
8	15	67,200	4,480	30	8	27,000	3,380
9	14	63,936	4,560	31	8	21,000	2,630
10	14	60,768	4,340	Sept. 1	8.5	28,500	3,360
11	13	62,400	4,800	2	8.5	30,000	3,52[illegible]

***Parallel observations of per cent volume of sediment and of turbidity, in terms of parts per million, of silica in water from Gila River, etc.*—Continued.**

Date.	Per cent sediment volume.	Turbidity (silica parts per million).	Conversion factor.	Date.	Per cent sediment volume.	Turbidity (silica parts per million).	Conversion factor.
Sept. 3	9	33,960	3,770	Sept. 29	0.5	650	1,300
4	8	36,000	4,500	30	.5	600	1,200
5	13	40,980	3,150	Oct. 1	Trace.	650	.....
6	15	42,000	2,800	2	2.5	350	.....
7	11	40,980	3,730	3	Trace.	650	.....
8	10	31,500	3,150	4	Trace.	280	.....
9	6.5	25,200	3,880	5	Trace.	220	.....
10	3.5	9,200	2,630	6	Trace.	6,400	.....
11	1.5	4,200	2,800	7	2	42,000	.....
12	1.5	3,150	2,090	8	10	42,000	4,200
13	5	14,000	2,800	9	13	39,000	3,000
14	7.5	20,000	2,670	10	12	36,000	3,000
15	4	13,000	3,250	11	13	27,000	2,080
16	6	16,000	2,670	12	9	18,000	2,000
17	6	16,000	2,670	13	5.5	12,000	2,180
18	5	13,000	2,600	14	3.5	8,000	2,280
19	5	11,320	2,260	15	2.5	4,400	1,760
20	4	12,000	3,000	16	2	3,800	1,900
21	2	6,300	3,000	17	1	3,750	3,750
22	1	5,500	5,500	18	7	26,000	3,720
23	3.5	8,000	2,280	19	2	6,000	3,000
24	14	30,000	2,140	20	1.5	3,000	2,000
25	17	30,000	1,760	21	.5	1,000	2,000
26	3	7,000	2,330	22	.3	900	3,000
27	2	8,000	4,000	23	.5	800	1,600
28	1	1,000	1,000	24	.5	766	1,530

TURBIDITY.

As all the usual methods for the determination of turbidity are fairly familiar, having been repeatedly described in numerous scientific journals, no further statements are necessary here. It is customary at the present time to adopt as a basis for the scale of each an absolute turbidity produced by a definite amount of finely divided silica in a certain volume of water. The scale has been described by its originators, Messrs. George C. Whipple and Daniel D. Jackson, in Technology Quarterly, Vol. XII, No. 4, December, 1899, pages 283–287.

UNITED STATES GEOLOGICAL SURVEY TURBIDITY ROD.

DESCRIPTION.

This rod, devised by Messrs. Allen Hazen and George C. Whipple, is a modification of the original Hazen rod, and is described in the following extract from circular No. 9 of the division of hydrography, United States Geological Survey:

Proposed turbidity standard.—The standard of turbidity shall be a water which contains 100 parts of silica per million in such a state of fineness that a bright platinum wire 1 millimeter in diameter can just be seen when the center of the wire is 100 millimeters below the surface of the water and the eye of the observer is 1.2 meters above the wire, the observation being made in the middle of the day, in the open air, but not in sunlight, and in a vessel so large that the sides do not shut out the light so as to influence the results. The turbidity of such water shall be 100.

The turbidity of waters more turbid than the standard shall be computed as follows: The ratio of the turbidity of the water to 100 shall be as the extended volume is to the original volume when the water is diluted with a clear water until the mixture is of standard turbidity.

The turbidities of waters lower than the standard should be computed as follows: The ratio of the turbidity of the water to 100 shall be as the ratio of the original volume of water of standard turbidity is to the extended volume when such water is diluted with clear water until its turbidity is equal to that of the water under examination.

This standard can be used in both field and laboratory. In the field the wire method will be employed as at present, except for a new graduation, while in the laboratory the methods of dilution and comparison now in use for the silica standard will be employed.

Method of application to the platinum-wire process.—A rod with a platinum wire inserted in it at a fixed point and projecting from it at a right angle will be used, as at present. The graduation shall be as follows: The graduation mark of 100 shall be placed on the head of the rod at a distance of 100 millimeters from the center of the wire. Other graduations will be made, based on the best obtainable data, in such a way that when a water is diluted the readings will decrease in the same proportion as the percentage of the original water in the mixture. Such a rod, having the graduation shown in the table below, shall be known as the United States Geological Survey turbidity rod of 1902. When this rod is immersed in water, the visibility of the projecting platinum wire at the depth from the surface shown in the second column will determine the degree of turbidity, as indicated in the first column.

Graduation of turbidity rod of 1902.

Turbidity.	Depth of wire.	Corresponding value on reciprocal scale.	Turbidity.	Depth of wire.	Corresponding value on reciprocal scale.
	mm.			mm.	
7	1,095	0.023	70	138	0.184
8	971	.026	75	130	.196
9	873	.029	80	122	.208
10	794	.032	85	116	.219
11	729	.035	90	110	.230
12	674	.038	95	105	.242
13	627	.041	100	100	.254
14	587	.043	110	93	.278
15	551	.046	120	86	.295
16	520	.049	130	81	.314
17	493	.052	140	76	.334
18	468	.054	150	72	.35
19	446	.057	160	68.7	.37
20	426	.060	180	63.4	.41
22	391	.065	200	57.4	.44
24	361	.070	250	49.1	.52
26	336	.076	300	43.2	.59
28	314	.081	350	38.8	.65
30	296	.086	400	35.4	.72
35	257	.099	500	30.9	.82
40	228	.111	600	27.7	.92
45	205	.124	800	23.4	1.09
50	187	.136	1,000	20.9	1.21
55	171	.148	1,500	17.1	1.49
60	158	.160	2,000	14.8	1.72
65	147	.172	3,000	12.1	2.10

This table is compiled from observations made at Cincinnati, St. Louis, New Orleans, Pittsburg, Brooklyn, Philadelphia, and Boston, for records of which we are indebted to several observers. The values of the turbidities by the reciprocal scale are included in the table for convenience, but they do not form a part of the standard.

This graduation is subject to revision whenever additional data shall make it necessary and revised rods shall be designated by the same name, but with the year of revision substituted for 1902. The revisions shall have as their basis the 100 mark, 100 millimeters from the wire.

Near the end of the rod, at a distance of 1.2 meters from the platinum wire, a wire ring shall be placed directly above the wire, through which the observer will look, the object of the ring being to control the distance from the wire to the eye.

When the turbidity is greater than 500 the water should be diluted before the observation is made. When the turbidity is below 7 this method can not be used, and comparison should be made with the silica standard properly diluted in bottles or tubes, as described by Whipple and Jackson in Technology Quarterly, Vol. XII, No. 4, December, 1899.

The number obtained by dividing the weight of suspended matter in parts per million by the turbidity as obtained above shall be called the coefficient of fineness. If greater than unity it indicates that the matter in suspension in the water is coarser than the standard; if less than unity, that it is finer than the standard.

This standard is proposed with the idea of combining the best features of the platinum-wire and silica methods of measuring turbidities as commonly used, and of avoiding, as far as possible, the objections to each.

OBJECTIONS TO ROD METHOD.

The method of turbidity determination above outlined answers all purposes demanded in ordinary use. In field determinations it has many objections which are not easily overcome. It was readily observed in practice that the method is largely a test of the individual and that the point at which the wire disappears from view varies according to the eyesight of the observer. Under ordinary conditions this variation is not sufficient to influence the interpretations placed upon the results, but there are some conditions under which the variation would be large enough to cause considerable error.

Again, the method was found to be inaccurate and unsafe in determining turbidity above 100. It is also difficult to select the conditions prescribed in the directions above set forth. A person in the field is governed absolutely by the conditions which he meets, and it is exceptional when he is able to be at a desired point at a given time. Therefore the observation, which must be made "in the middle of the day, in the open air, but not in sunlight, and in a vessel so large that the sides do not shut out the light," is in most cases an undertaking of extreme difficulty. Another observation is more important; it is necessary for the field man to take observations in the running stream. Obviously it would be impracticable to carry about a container large enough to meet these prescribed conditions, and in the majority of cases a turbidity reading must be taken at long distances from points at which such containers can be borrowed. It is well known that in many cases the suspended matter in running streams occurs in clouds. In a certain section of the stream the turbidity at one moment may be high and at the next moment much reduced, or vice versa. Often the observer, after fixing the point at which the platinum wire disappears, finds that before he is able to read the scale the wire is either plainly in sight or has become submerged below the point of correct turbidity reading.

All these objections make the use of the turbidity rod undesirable in general field work. While its value at selected stations is acknowledged, it has been found to be impracticable under less favorable circumstances; consequently a new method was sought.

JACKSON'S TURBIDIMETER.

DESCRIPTION.

The needs of the Survey were found to be met in a satisfactory manner by the use of a turbidimeter devised by Mr. Daniel D. Jackson, chemist in charge of the Mount Prospect laboratory, department of water supply, gas, and electricity, city of New York. The following is a report by Mr. Jackson with reference to this instrument:

The suspended matter or turbidity in natural waters is the most important physical characteristic in many sections of the country. In such sections the selection of new water supplies, as well as the improvement of existing supplies, rests, to a very great extent, upon a consideration of this particular feature. These milky or muddy waters are often quite variable in the amount and nature of their suspended matter, and, in case they are to be purified, require considerable study to determine the proper treatment.

When the maximum and the average turbidity in a water are known, questions may be solved relating to the nature, size, and construction of settling basins, filter plants, and clear-water reservoirs, and, finally, in determining the efficiency of the removal of suspended matter in such filter plants we must know the turbidity of the water before and after filtration.

The hydrographic branch of the United States Geological Survey is particularly interested in developing accurate and rapid methods for the determination of turbidity, both for data relating to water supplies as well as relating to the erosion and the carrying power of suspended matter by rivers and streams. It is necessary that the field methods should be comparable with those of the laboratory, that the work should be rapidly accomplished, and that the results should express, as nearly as possible, the actual weight of the suspended matter present.

If we determine the total solids in a water before and after filtration through a Berkfeld filter, the difference in the results obtained will give the weight of the suspended matter present, but this method is tedious in the laboratory and impossible in the field. It is evident that some photometric standard of comparison must be used, and extensive studies have shown that whatever the instrument employed for this purpose it should be graduated by a standard turbid water. The standard now employed is known as the "silica standard," and is made from diatomaceous earth.[a]

This standard is preferable to all others that have been used in that it is absolutely insoluble, has a very uniform size of particle, and, unlike clay, does not cake together on standing. The diatomaceous earth (infusorial earth) is found in natural deposits in many parts of the country. To prepare the standard this material is first washed and ignited to free it from organic matter. It is then ground to an impalpable powder in an agate mortar, put through a 200-mesh sieve to break up the lumps produced in grinding, treated with dilute hydrochloric acid, and the finest portion decanted. This fine portion is then dried at 100° C., cooled in a desiccator, and kept in a tightly stoppered bottle.

[a] Whipple, G. C., and Jackson, D. D., Silica standards for the determination of the turbidity in water: Techn. Quart., vol. 12, No. 4, Dec., 1899.

JACKSON'S CANDLE TURBIDIMETER.

)ne gram of this material is weighed out and put into 1 liter of distilled water. e mixture represents a standard of 1,000 parts per million of silica turbidity, d dilutions may be made from this for comparison with natural waters. adings made with this standard compare very well with the actual weight the suspended matter in water, but it has been found that the standard as epared varies slightly when made by different analysts. The author now proses to make the standard absolute by making readings on the candle turbidim-r and so adjusting the mixture that the standard of 1,000 parts per million ll always read 2.3 centimeters on the instrument.

THE CANDLE TURBIDIMETER.

The original form of this instrument was first described by the writer in the urnal of the American Chemical Society, November, 1901, but since that time has been considerably improved upon. The accompanying illustration gives good idea of the present form of the instrument and its use. [See Pl. I.] The paratus consists of a glass tube, closed at the bottom and graduated in centiters and millimeters depth. This is surrounded by a brass holder, open at the ttom and supported by a stand, in the center of which is a standard English ndle, so adjusted by means of a spring below that its top rim is always just nches below the bottom of the glass tube.

The water to be determined for turbidity is poured into the glass tube until the age of the lighted candle below just disappears.[a] The depth of the water in the be is then read (using the bottom of the meniscus), and this depth is compared th a table which gives the turbidity of the water in parts per million of ica. The tube itself may be graduated in turbidity as well as in millimeters pth, thus dispensing with the use of the table. Between 5,000 and 100 parts r million of silica a tube 25 centimeters in length is necessary, or a comparison th silica standards in tubes or bottles may be substituted. The candle instrument is very convenient in the laboratory, and as its source of light is the standd candle it is ready for use at all times. The candle must always be properly immed, and the determination must be made rapidly, so as not to heat the quid to any extent. The most accurate work is obtained in a dark room, and e candle should be so placed as not to be subjected to a draft of air. The tter necessity renders the instrument absolutely impossible for use in the ld.

Several forms of field apparatus in which the candle was employed as a urce of light were attempted, but were entirely unsuccessful, and it was found cessary to resort to the electric light for field use.

THE ELECTRIC TURBIDIMETER.

This instrument was designed by the author for the use of the hydrographic anch of the United States Geological Survey, and is intended for field use ly. Its construction is so regulated as to be exactly comparable with the ndle turbidimeter, and the measuring tubes for each have been made interangeable.

The electric turbidimeter as shown in fig. 1 consists of the same graduated ass tube as described for the candle turbidimeter, inclosed in a similar manner

[a] It has been found in actual field work that the end point in the electric turbidimeter, z, the disappearance of the cross of light, is generally sharper and less subject to pernal errors than the end point above designated. This is especially true when the two struments are used by the same person, i. e., a common end point is more satisfactory. he Geological Survey has therefore placed the glass plate and cross disk in the candle rbidimeter.

by a brass holder (*A*) open at the bottom. This holder is attached to the end of a brass cylinder (*m*) containing a 2.5-volt dry battery (*C*) and a 2.5-volt electric light (*d*). Above the electric-light bulb, at a distance of 1 centimeter, is a disk of glass (*e*) which is ground on the under side. Immediately above this is a brass disk (*b*) 1 millimeter thick, through the center of which a cross is cut (*B*). The lines in this cross are 0.5 millimeter wide. From the top of the brass plate to the bottom of the graduated glass tube the distance is just 1 centimeter.

To make a determination with the electric turbidimeter, first pour the turbid water to be tested back and forth from the glass tube to another vessel until it is thoroughly mixed, and then turn on the light by adjusting the screw (*f*) at the bottom of the instrument. Place the graduated glass tube in the holder, which has been screwed into place above the light, and pour the turbid water into the tube until the cross of light just disappears. If the tube is not graduated directly in parts per million of silica, read the depth in millimeters of the water in the tube and refer to the table given later. In reading use the bottom of the meniscus as the reading point. In the lower part of the tube read past the disappearance of the sharp cross of light to the disappearance of the hazy cross of light. In this way the end point is the same as in the candle turbidimeter. Higher up in the tube there is only the sharp cross of light for an end point.

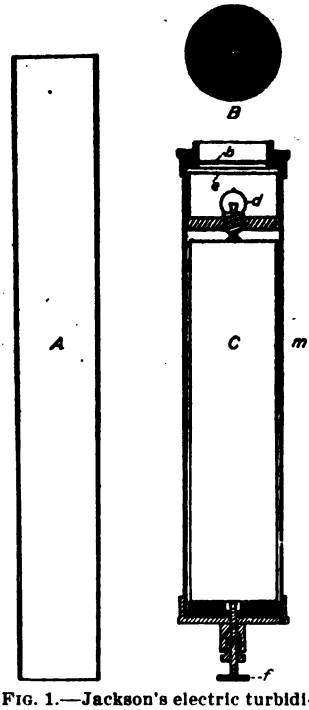

FIG. 1.—Jackson's electric turbidimeter.

If the turbidity is above 100 parts per million use the short tube (25 centimeters long). If the turbidity is between 100 parts and 25 parts per million the long tube (75 centimeters) may be employed, but at any point below 100 the glass tube and the holder may be removed and the instrument lowered directly into the turbid water by means of a steel millimeter tape. Any degree of turbidity may be read in this manner provided the water is sufficiently deep.

If the water is shallow and below 25 turbidity, close estimations may be made by holding a bottle of the water toward the light and comparing it with the remembered appearance of standards of 5, 10, 15, and 20 parts per million in bottles of the same size.

In the determination of turbidity with Jackson's turbidimeter many of the objections to the use of the United States Geological Survey turbidity rod are avoided. As the standard illumination is a part of the apparatus itself rather than the sun, none of the limitations which apply to the use of the rod, such as time of day, shade, etc., are necessary considerations. The instrument may be used at night if desired. As the sample to be tested is collected from the body of water under observation, inaccuracies due to moving water and variations in turbidity caused thereby are avoided, and it is not

sults of tests of 6-inch 2-cell "Reliable" battery—Continued.

BATTERY NO. 3.

At end of—	Current.	Loss.	E. M. F.	Light.
	Ampere.	*Ampere.*	*Volts.*	
.....	0.273	.....	2.82	Bright.
.....	.270	0.003	.....	
.....	.265	.005	.....	
.....	.262	.003	.....	
.....	.260	.002	.....	
.....	.258	.002	.....	
.....	.255	.003	.....	
.....	.253	.002	.....	
.....	.252	.001	.....	
.....	.251	.001	.....	
.....	.250	.001	2.60	Bright.
		.023		

BATTERY NO. 3 AFTER REST OF 90 MINUTES.

.....	0.256	.....	2.70	Bright.
.....	.252	0.004	.....	
.....	.249	.003	.....	
.....	.246	.003	.....	
.....	.244	.002	.....	
.....	.243	.001	.....	
.....	.242	.001	.....	
.....	.241	.001	.....	
.....	.240	.001	.....	
.....	.239	.001	.....	
.....	.238	.001	2.50	Bright.
		.018		

tteries were next tested for recuperation by alternating one
: use with five minutes of rest, as follows:

BATTERY NO. 1.

Period.	Initial current.	Final current.	Drop in current.	Initial voltage.	Final voltage.	Drop in voltage.
	Ampere.	*Ampere.*	*Ampere.*			
te	0.243	0.238	0.005	2.60	2.54	0.06
ute	.242	.237	.005	2.56	2.51	.05
ite	.241	.237	.004	2.56	2.50	.06
ute	.240	.238	.002	2.56	2.50	.06
te	.240	.236	.004	2.57	2.50	.07

Results of tests of 6-inch 2-cell "Reliable" battery—Continued.

BATTERY NO. 1 AFTER A REST OF 90 MINUTES.

At end of—	Current.	Loss.	E. M. F.	Ligh
	Ampere.	*Ampere.*	*Volts.*	
0 minute	0.250		2.66	Brigh
1 minute	.245	0.005		
2 minutes	.243	.002		
3 minutes	.241	.002		
4 minutes	.239	.002		
5 minutes	.237	.002		
6 minutes	.236	.001		
7 minutes	.235	.001		
8 minutes	.235	.000		
9 minutes	.234	.001		
10 minutes	.234	.000	2.50	Bright
		.016		

BATTERY NO. 2.

0 minute	0.272		2.80	Bright
1 minute	.268	0.004		
2 minutes	.265	.003		
3 minutes	.263	.002		
4 minutes	.261	.002		
5 minutes	.258	.003		
6 minutes	.255	.003		
7 minutes	.253	.002		
8 minutes	.251	.002		
9 minutes	.250	.001		
10 minutes	.249	.001	2.63	Bright
		.023		

BATTERY NO. 2 AFTER A REST OF 90 MINUTES.

0 minute	0.263		2.70	Bright
1 minute	.258	0.005		
2 minutes	.253	.005		
3 minutes	.252	.001		
4 minutes	.250	.002		
5 minutes	.248	.002		
6 minutes	.246	.002		
7 minutes	.245	.001		
8 minutes	.244	.001		
9 minutes	.243	.001		
10 minutes	.243	.000	2.52	Bright
		.020		

esults of tests of 6-inch 2-cell "Reliable" battery—Continued.

BATTERY NO. 3.

At end of—	Current.	Loss.	E. M. F.	Light.
	Ampere.	*Ampere.*	*Volts.*	
	0.273		2.82	Bright.
	.270	0.003		
	.265	.005		
	.262	.003		
	.260	.002		
	.258	.002		
	.255	.003		
	.253	.002		
	.252	.001		
	.251	.001		
s	.250	.001	2.60	Bright.
		.028		

BATTERY NO. 3 AFTER REST OF 90 MINUTES.

	0.256		2.70	Bright.
	.252	0.004		
	.249	.003		
	.246	.003		
	.244	.002		
	.243	.001		
	.242	.001		
	.241	.001		
	.240	.001		
	.239	.001		
s	.238	.001	2.50	Bright.
		.018		

atteries were next tested for recuperation by alternating one of use with five minutes of rest, as follows:

BATTERY NO. 1.

Period.	Initial current.	Final current.	Drop in current.	Initial voltage.	Final voltage.	Drop in voltage.
	Ampere.	*Ampere.*	*Ampere.*			
ute	0.243	0.238	0.005	2.60	2.54	0.06
nute	.242	.237	.005	2.56	2.51	.05
ute	.241	.237	.004	2.56	2.50	.06
inute	.240	.238	.002	2.56	2.50	.06
ute	.240	.236	.004	2.57	2.50	.07

BATTERY NO. 2.

Period.	Initial current.	Final current.	Drop in current.	Initial voltage.	Final voltage.	Drop in voltage.
	Ampere.	*Ampere.*	*Ampere.*			
First minute	0.249	0.245	0.004	2.63	2.56	0.07
Second minute	.249	.245	.004	2.63	2.56	.07
Third minute	.248	.245	.003	2.63	2.56	.07
Fourth minute	.247	.243	.004	2.62	2.56	.06
Fifth minute	.247	.243	.004	2.63	2.60	.03

BATTERY NO. 3.

First minute	0.260	0.255	0.005	2.76	2.66	0.10
Second minute	.257	.253	.004	2.72	2.66	.06
Third minute	.255	.251	.004	2.70	2.63	.07
Fourth minute	.254	.250	.004	2.70	2.63	.07
Fifth minute	.253	.249	.004	2.66	2.60	.06

	Volts.
Highest voltage observed	2.82
Lowest voltage observed	2.50
Extreme variation	.32

Reckoned on an average voltage of 2.66 volts, this is a variation of 12 per cent.

	Ampere.
Highest amperage observed	0.273
Lowest amperage observed	.234
Maximum variation	.039

Reckoned on an average amperage of 0.248 ampere this is a variation of 16 per cent in current. The drop in current averages 0.002 ampere per minute, or about 0.8 per cent.

It will be seen from these results that the battery is quick in recovery and that while in use the reduction in electromotive force is comparatively small. The change in current observed in the batteries tested does not cause any error in a turbidity estimation. Readings were made at different times with a standard of turbidity corresponding to 250 parts per million of silica, and in every case the variation in depth of liquid read in the graduated tube came within the probable deviation occurring in reading. The ordinary variation of current in the battery does not affect the accuracy of the instrument to a measurable degree.

This battery will remain effective under ordinary conditions from fifty to sixty days, at the end of which time it is advisable to change the cartridge.

Electric-bulb test.—Several lights were tested to see if there were a noticeable deviation in the intensity of light produced. The test of four sample lights is here given:

Battery.	Lamp No. 1.	Lamp No. 2.	Lamp No. 3.	Lamp No. 4.
No. 1	8.7	8.5	8.4	7.7
No. 2	8.6	8.6	8.2	8.0
No. 3	8.9	8.5	8.3	7.9

The numbers given are the depths in centimeters produced by using a standard turbidity of 250 with different batteries and lights. The mean of these observations is 8.4, while the average deviation from the mean is 0.3, which brings three of the lamps within the limit allowed on individual readings under constant conditions; the fourth light, however, falls without the limit of error. The lamps were chosen at random from a stock of 2.5-volt lights. It is evident that here is a variation which must be overcome. It may be done by buying a large stock of lamps and selecting only such as come within the standard conditions, or by buying lamps of guaranteed candle power. In conclusion it may be said that it is well to test a new lamp with silica standard before using it in the field.

Glass-plate test.—The glass diaphragm placed over the lamp is ground on one side in order to tone and diffuse the rays from the electric light. It also makes possible the use of a much shorter glass tube than would otherwise be necessary, and it reduces variation in candlepower in the effect thereof on turbidity determinations. It appears to be possible to procure glasses which are ground to the same opacity. Different glasses were tried in the instrument without any apparent effect on the depth of turbid liquid required to shut off the light. It may be said in connection with the ground glass that the cross slit of brass above it should be constant in width of aperture. As this offers no mechanical difficulties, no experiments were made to determine the effect of variation in the width of the slit.

Calibration for turbidity.—When work was begun on the calibration of the instrument it was necessary to prepare a standard silica solution. The standard heretofore used has been very difficult to match on account of the difficulty of grinding the silica fine enough to reach the required turbidity. The standard is such that it gives a reading of 500 parts per million at a depth of 4.5 centimeters, while the standard prepared by ordinary grinding gives a reading of 500 parts per million at a depth of about 5.7 centimeters. Several

Calibration of turbidimeter for standard of 200 parts per million turbidi

[Centimeters. Excess of average deviation indicated by italic figures.]

Reading.	Deviation.	Reading.	Deviation.
11.3	*0.3*	10.6	*0.4*
11.1	.1	11.3	*.3*
11.1	.1	11.1	.1
11.0	.0	11.1	.1
11.0	.0	11.0	.0
10.9	.1	11.0	.0
11.5	*.5*	10.9	.1
10.6	*.4*	187.3	2.9
11.1	.1		
10.7	*.3*		

Mean=187.3÷17=11.0. Average deviation=2.9÷17=0.2.

The deviation of 6 of the 17 observations exceeds 0.2 centime
he average deviation. Only 3 observations exceed 0.3 centimeter
leviation. Under ordinary circumstances we may consider 0.3 c
imeter as the average deviation.

Calibration of turbidimeter for standard of 100 parts per million turbidit

[Centimeters. Excess of average deviation indicated by italic figures.]

Reading.	Deviation.	Reading.	Deviation.
21.9	0.2	21.9	0.2
21.5	.2	22.2	*.5*
21.6	.1	21.0	*.7*
21.1	*.6*	21.9	.2
22.2	*.5*	21.5	.2
21.0	*.7*	21.9	.2
21.9	.2	303.1	4.7
21.5	.2		

Mean=303.1÷14=21.7. Average deviation=4.7÷14=0.3.

The deviation of 5 of the 14 observations exceeds 0.3 centime
the average deviation. Probably 0.4 centimeter would be the o
nary deviation. If we reckon 0.4 as the average deviation, mea
21.8. Probably 21.7 is correct.

ration of turbidimeter for standard of 125 parts per million turbidity.

[Centimeters. Excess of average deviation indicated by italic figures.]

Reading.	Deviation.	Reading.	Deviation.
17.3	0.0	17.2	.1
16.7	*.6*	17.5	.2
17.2	.1	17.4	.1
17.4	.1	155.6	1.5
17.3	.0		
17.6	*.3*		

Mean = 155.6 ÷ 9 = 17.3. Average deviation = 1.5 ÷ 9 = 0.2.

average deviation from 9 readings is 0.2 centimeter and is ed by only 2 readings. Probably more readings would give r deviations and the average deviation would be increased.

ration of turbidimeter for standard of 500 parts per million turbidity.

[Centimeters. Excess of average deviation indicated by italic figures.]

Reading.	Deviation.	Reading.	Deviation.
4.4	0.1	4.6	.1
4.6	.1	4.5	.0
4.5	.0	31.4	.5
4.4	.1		
4.4	.1		

Mean=31.4÷7=4.5. Average deviation=0.5÷7=0.1.

ugh only 7 readings are here given, many more were taken ıt getting anomalous results. The probable deviation is 0.1 ıeter and will not be exceeded. Mean=4.5 centimeters.

bidity of 1,000 parts per million.—From many observations erent times, 2.3 centimeters is the reading for 1,000 standard.

Average deviation=0.1 centimeter.
Mean =2.3 centimeters.

have, then, determined by actual experiment the depth cor- ıding to 6 turbidities:

urbidity	100	125	200	250	500	1,000
›epth (centimeters)	21.7	17.3	11.0	8.7	4.5	2.3

These points are then plotted on logarithmic cross-section paper (fig. 2) and intermediate points determined by measurement on the plot.

Below 100, depths have been determined at 50 and at 25 by using a longer tube, with which the effect will be the same as lowering the light into the standard by means of a tape. The observations made

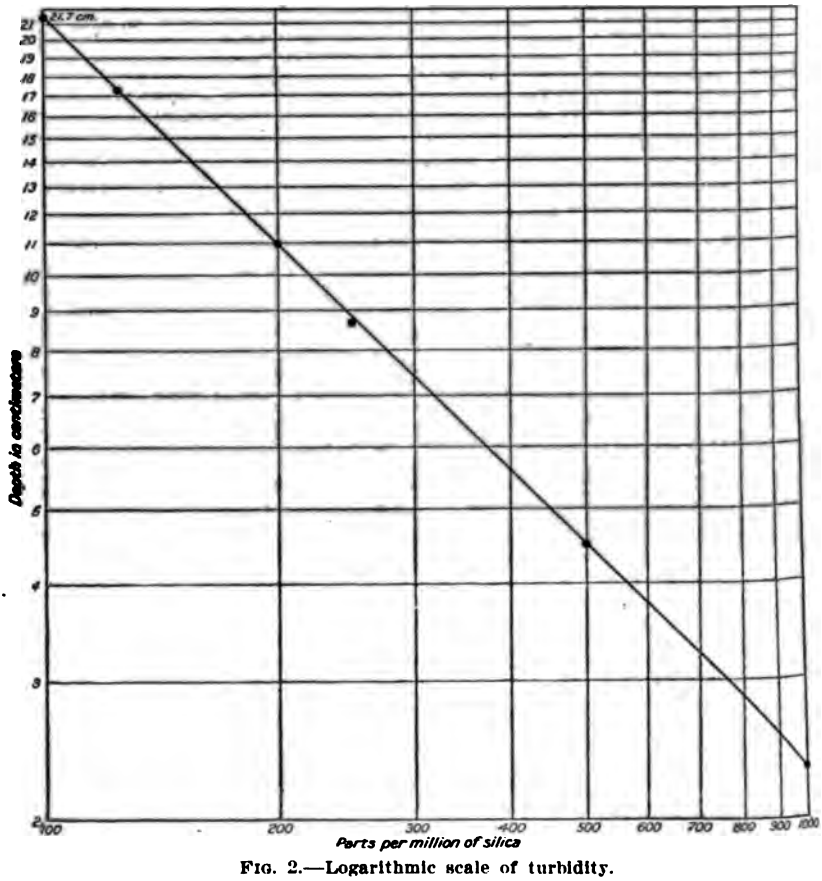

FIG. 2.—Logarithmic scale of turbidity.

at 50 and 25 seem to indicate that the curve begins to swing away from its course at 100. This change may be due to the fact that the distance between light and eye is increased. From 1,000 to 100 the light is 25 centimeters from the eye; at 50 it is 40 centimeters away, while at 25 the distance is 65 centimeters. The readings are as follows:

tion of turbidimeter for standard of 50 and 25 parts per million turbidity.

[Centimeters.]

50 parts.
36.1
34.0
34.5
34.4
35.3
35.0
34.3
34.1
33.9
35.2
346.8

Mean=346.8÷10=34.7.

[Centimeters.]

25 parts.
64
61
56
61
63
60
65
430

Mean=430÷7=61.

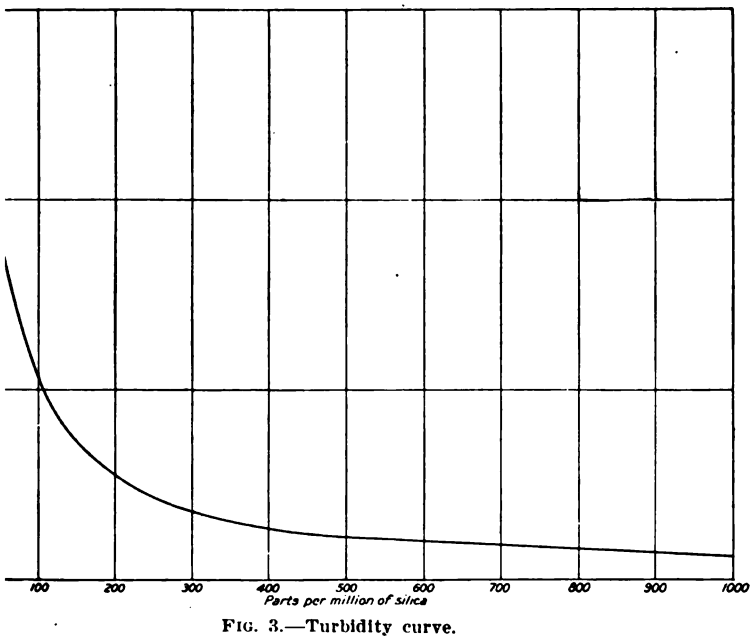

FIG. 3.—Turbidity curve.

These readings may not be accurate. Further experiments show that they are too low. At most, however, they are with parts per million of silica in their relation to the real values (fi The limit of accuracy between 100 and 1,000 is well-defined fron points determined.

From the values heretofore determined the depths of liquid ir turbidimeter corresponding to a silica standard of turbidity ar forth in the following table:

Turbidity determinations.

Depth.	Silica.	Depth.	Silica.
Cm.	*Parts per million.*	*Cm.*	*Parts per million.*
2.3	1,000	10.5	210
2.6	900	11.0	200
2.9	800	11.5	190
3.2	700	12.1	180
3.5	650	12.8	170
3.8	600	13.6	160
4.1	550	14.4	150
4.5	500	15.4	140
4.9	450	16.6	130
5.6	400	18.0	120
6.3	350	19.6	110
7.3	300	21.7	100
7.6	290	23.0	90
7.8	280	25.0	80
8.1	270	28.0	70
8.5	260	31.0	60
8.7	250	35.0	50
9.1	240	42.0	40
9.5	230	52.0	30
10.0	220	70.0	20

DETERMINATION OF THE PROBABLE ERROR.

Readings on the same standard solution with the same bat and light by the same person will vary within narrow limits. T limits have been determined for several points and calculate average deviation.

Limits of accuracy on duplicate readings.

Standard.	Average deviation in centimeters.	Limit of accuracy in parts per million.
1,000	0.1	Reading correct within 35 parts.
500	.1	Reading correct within 15 parts.
250	.3	Reading correct within 10 parts.
200	.3	Reading correct within 8 parts.
100	.4	Reading correct within 5 parts.
50	.....	Reading correct within 5 parts.
30	.....	Reading correct within 5 parts.

n other words, a turbidity between 500 and 1,000 parts can be .sured accurately within 35 parts. Between 200 and 500 parts .surement can be made within 10 to 15 parts, and between 50 and within 5 to 8 parts per million.

he limit of accuracy is not changed by change of observers. Since thing seen is a ray of light, it appears to be visible to any eye and ears to be shut off at the same depth for different observers.

he limit is greater than that change in depth caused by normal iations in the current. Therefore the limit of accuracy is not eased by variations in the battery within ordinary limits.

hanges in the electric bulb can introduce a constant error greater n the probable error in determination. Therefore only such ips should be used as have been tested with a standard silica ition.

n the general field work of the hydrographic branch the field istants and those cooperating are instructed to use the Jackson turimeter in connection with all waters having a turbidity of more n 100, while the turbidity rod could be used in waters having a er turbidity. The objections mentioned in connection with the of this rod are not so serious in the determination of low turities.

COLOR.

OCCURRENCE.

The term "color" as used in water chemistry should not be conuded with the term as ordinarily used. The streams of the Mississpi Valley, and indeed the great river itself, appear highly colored. e will find rivers which are habitually red, yellow, brown, or black appearance. This color is not due to the water itself, but to the racter of the matter which is carried in suspension. It is a factor the turbidity, and reveals the nature of the geologic formations ded by the flowing water. On the other hand, waters may have a

color due to dissolved substances, and this is the feature referred to by the term as used in water analysis.

In those parts of the United States where the underlying rock is resistant—that is, where it does not readily break up and disintegrate under the forces of erosion—we usually find colored water. At first sight it seems paradoxical that the clear waters of New England, many of which drain from granitic formations and hills of gravel, are colored, while those of the Central West, which carry large amounts of suspended matter eroded from the surface, are, when freed from turbidity, nearly colorless. In many cases this is due to the fact that the substances in suspension are of such nature that they absorb any color which might have been dissolved. On the other hand, in New England streams the color due to the decay of vegetable matter, such as peat or muck, remains in solution, and while the water is generally very clear the color itself is apparent in varying degrees.

The importance of the color determination arises from the fact that in public supplies consumers demand a clear, colorless liquid, and are reluctant to accept any other. In manufacturing processes a colored water often works harm. In certain classes of waters the dissolved color is a fair index of the amount of organic matter contained. These facts pertain primarily to unpolluted water, for it is apparent that a water contaminated by wastes may have colors arising from sources such as dyes, sediments, etc. On the whole, the color of a natural water which can be applied to domestic and manufacturing purposes affects its value along economic lines. The periodical determination of dissolved color is necessary, as its intensity varies with the seasons and is influenced by sunlight, precipitation, and various other natural phenomena.

COLOR STANDARDS.

GEOLOGICAL SURVEY STANDARD.

The standard of color determinations adopted by the United States Geological Survey is known as the platinum-cobalt method, devised by Mr. Allen Hazen, from whom so many practical and extremely valuable ideas with reference to the determination of quality of water have come.

The method is as follows:

A standard solution which has a color of 500 is made by dissolving 1.246 grams potassium-platinic chloride[a] ($PtCl_4,2KCl$), containing 0.5 gram platinum, and 1 gram of crystallized cobalt chloride ($CoCl_2,6H_2O$), containing 0.25 gram of cobalt in water, with

[a] Potassium-platinous chloride is a salt that is often substituted by dealers in place of the potassium-platinic chloride. It is sometimes incorrectly labeled. The platinous salt has a reddish color, while the platinic salt has a yellow color.

100 cubic centimeters concentrated hydrochloric acid, and making up to 1 liter with distilled water. By diluting this solution, standards are prepared having values of 0, 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, and 70. The numbers correspond to the metallic platinum in the solutions in parts per million. These are kept in 100 c. c. Nessler jars of such diameter that the liquid shall have a depth between 20 and 25 centimeters and shall be protected from dust. The color of a sample is observed by filling a similar tube with water and comparing it with the standards. The observation is made by looking vertically downward through the tubes upon a white surface placed at such an angle that light is reflected upward through the column of liquid. The reading is recorded to the nearest unit. Waters that have a color darker than 70 are diluted before making the comparison, in order that no difficulties may be encountered in matching the hues. Water containing matter in suspension is filtered until no visible turbidity remains. If the suspended matter is coarse, filter paper may be used for this purpose; if the suspended matter is fine, the use of the Berkfeld filter is recommended. The use of a Pasteur filter is to be avoided, as it exerts a decolorizing action.

It is impracticable to carry the standard tubes above described into the field for observations, and yet field observations are of great convenience and value to the sanitary engineer, and in general to the investigations of the United States Geological Survey.

FIELD STANDARDS.

DESCRIPTION.

Disks of colored glass have been prepared by Mr. Allen Hazen, in cooperation with the Survey, as standards for measuring color of water in the field.[a] These disks have been rated by Mr. George C. Whipple to correspond with the platinum-cobalt standard. The color is measured by balancing the color of the water in a metallic tube with glass ends against the colors of glass disks of known value. The number on each disk represents the corresponding color of a water. This is not a new standard, but a new application of an old standard. The glass disks are rated to correspond with the platinum-cobalt color standard. The process bears the same relation to the usual laboratory process that an aneroid barometer bears to a mercurial barometer. The metallic tubes and glass standards are more portable and better adapted to field use than the Nessler tubes and color solutions heretofore used. The standards are disks of amber-colored glass, mounted with aluminum. Each disk carries two numbers. One number is over 100, and is a serial number for the purpose of identification.

[a] Pressey, H. A., Observations on flow of rivers in vicinity of New York City: Water-Sup. and Irr. Paper No. 76, U. S. Geol. Survey, 1903, Pl. X.

The other number is less than 100, and shows the color value of the disk; that is to say, the color of each disk is equal to the color of a solution of the designated number of parts per million of platinum with the required amount of cobalt to match the hue when seen in a depth of 200 millimeters. When a water comes between two disks its value can be estimated between them by judgment. Two or more disks can be used, one behind the other, in which case their combined value is the sum of the individual values. By combining the disks of a series in different ways a considerable number of values can be produced, allowing the closer matching of many waters.

USE OF FIELD STANDARDS.

Filling the tubes.—The tube, having an aluminum stopper, is to be filled with water, the color of which is to be determined. Rinse the tube once or twice by filling and emptying it. The second tube, having the clips to hold the glass disks, is made much like the one holding the water, to facilitate comparison. Theoretically this tube should be filled with distilled water. Practically it makes very little difference whether it is filled with distilled water or empty. Use distilled water when it is convenient to do so, and when distilled water of unquestionable quality is at hand; otherwise wipe the inside of the tube dry to prevent fogging of the glass ends, and proceed with the tube empty.

Holding the tubes.—Hold the tubes at such a distance from the eye that the sides of the tubes just can not be seen. This occurs when the near end of the tube is 8 or 9 inches from the eye. Hold the tubes at such an angle that both can be seen at once with one eye. Good results can not be obtained in any other way. Interchange the tubes once or twice, as sometimes the light on the right and left is not quite equal.

Background.—There should be a clear white background with a strong illumination. The best results can not be obtained with either too little or too much light. In a gray day look at the sky near the horizon away from the sun. In a bright day look at a piece of white paper or tile upon which a strong light falls. The white surface may be vertical and the tubes held horizontally, or the tubes may be held at an angle directed downward toward a horizontal surface, as may be most convenient. Good results can not be obtained by artificial light.

Turbid water.—The colors of very turbid waters can not be measured in this way. Slight turbidities do not interfere seriously with the results. Waters too turbid for direct observations should be filtered through thick filter paper before being tested; and in case the suspended matter causing the turbidity is fine in grain and large

in amount, even this method may fail. The turbidity of water should be taken as far as possible in connection with color observations, except in cases where it is obvious from inspection that there is practically no turbidity.

Highly colored waters.—Some waters will be found having a higher color than can be matched by the standards. In general, waters with colors above 100 should not be matched in 200-millimeter tubes, and the results with waters having colors below 80 will be considerably more accurate than with more highly colored ones. Two procedures are possible with waters having higher colors; namely, to dilute with distilled water before measuring the color, or to use shorter tubes. The latter procedure is the more convenient, but both are equally accurate. To measure the color with short tubes, put the highly colored water in a tube of one-half the usual length and match as usual. It is not necessary to have a short standard holder. The 200-millimeter tube can be used. After the water is matched the result is multiplied by 2. In case the color is too high to be read in a 100-millimeter tube it can be put in a 50-millimeter tube, and the result multiplied by 4. When dilution is used the highly colored water is mixed with one or more volumes of distilled water, the color matched, and the result multiplied by a corresponding factor. The tube itself can be used for measuring the colored water and the distilled water, and the mixing can be done in a tumbler or any convenient clean vessel.

Cleaning the tubes.—Always keep the tubes clean. Take particular care of the glass ends. All the ends are removable for the purpose of cleaning, and should not be screwed on too tightly. They should be water-tight when screwed up only loosely, for if screwed on hard they may stick so as to come off with difficulty.

IRON.

One of the important determinations which it is necessary to include in many special investigations is that of iron. Water containing an appreciable amount of this metal can not be used in many manufacturing processes. It is objectionable in domestic uses by reason of its taste and the discoloration of linen. Certain solutions of iron in boiler feed waters are particularly destructive. Iron in ground waters stimulates the growth of *Crenothrix*, which frequently clogs water pipes. On the other hand, iron has a certain medicinal value, and when it is in the form of sulphate has valuable coagulating properties. The last-named effect is well demonstrated in streams draining coal regions.[a]

[a] Leighton, M. O., Quality of water in Susquehanna River drainage basin: Water-Sup. and Irr. Paper No. 108, U. S. Geol. Survey, 1904, p. 36.

Colorimetric methods are believed to be the simplest and best for the determination of iron in natural waters, and they readily lend themselves to modification for field purposes. That which involves the use of potassium ferrocyanide, described on page 226 of Sutton's Volumetric Analysis, ninth edition, was selected as best adapted for the purposes in view. The process involves the addition of acid and KCNS to the water under investigation or to the residual solution of that water, thereby producing a characteristic blood-red color. The depth of this color is absolutely fixed by the amount of iron in the water. It is then necessary to add to a similar mixture, made up with distilled water, such a quantity of standard iron solution as will produce in this solution exactly the same shade of red as is shown in the water under investigation. Then from the amount of standard iron solution used to produce that shade of red the amount of iron in the water under investigation may easily be determined.

The modification of this method for field purposes consists of the use of fixed color standards, each having been previously rated to correspond with some known equivalent of iron. The apparatus used in the work is that already described for the determination of natural color. (Pl. II.) The color standards are red glass disks, rated and used in precisely the same way as the natural color standards. The colored light is transmitted directly through the disk tube, and the disks may be changed or combined until the color of the sample under examination is matched. Then from the rating of the disks the amount of iron may be stated.

A sample of the clear water to be tested is poured into a 50- or 100-c. c. graduate to the 45 c. c. mark, 2 cubic centimeters of concentrated nitric acid added, and the contents thoroughly mixed in order to convert all ferrous iron present into ferric iron. The fluid should then be allowed to stand about five minutes.

The mixing and oxidation is preferably accomplished by pouring the solution from the graduate into another vessel, such as the glass turbidimeter tube, and vice versa, at least eight or ten times. To the acidified solution in the graduate is then added 3 cubic centimeters of a solution of potassium sulphocyanide containing 20 grams KCNS per liter, and the liquids are thoroughly mixed and allowed to stand 10 minutes. The solution is now transferred to the aluminum colorimeter tube, which has a capacity of about 45 cubic centimeters and is about 8 inches long.

Nitric acid is used in the above method instead of hydrochloric acid, commonly employed, in the first place to avoid any corrosion of the aluminum tube, the desirability of the use of which will be explained later. With the employment of nitric acid instead of hydrochloric acid, moreover, it was discovered that the color produced in

TUBES AND DISKS FOR DETERMINING COLOR OF WATER.

iron solutions by the addition of sulphocyanide is somewhat deeper and does not fade nearly so rapidly. Finally, the addition of nitric acid not only effects the required acidity of the solution essential to the test, but obviates the need of employing potassium permanganate in order to convert any ferrous iron present to the ferric state.

The aluminum tube is employed in the assay for iron in natural waters, because (1) it is light, (2) it can not be easily broken in transportation, like the glass tubes used in the water laboratories, (3) it is provided with a suitable spring for supporting the colored-glass disks, (4) it provides a suitable depth of column of the water for the iron determination, and (5) it is generally used by the hydrographic division in determining the natural colors of waters. The aluminum colorimeter tube thus serves a double purpose, and obviates the necessity of carrying special tubes in the field for the iron assay.

The results reached by this method of determination should be as accurate for practical purposes as those attained by the laboratory method.

CHLORIDES.

The determination of chlorides in water is significant in two general lines of investigation. In connection with sanitary analyses, it is in certain parts of the country a valuable index of sewage pollution. In analyses of water for boiler and industrial purposes it is also important, as the chlorides of calcium and magnesium corrode boiler plates.

LABORATORY DETERMINATION.

With reference to the determination of chlorides from a sanitary standpoint, the following article by Mr. Daniel D. Jackson, chemist in charge of the Mount Prospect laboratory, department of water supply, gas, and electricity, of New York City, is presented:

Chlorine, a constituent of common salt, is present in nearly all natural waters. Its original sources are mineral salt deposits and finely divided salt spray from the sea. This latter is carried with dust particles by the wind and precipitated with the rain. All salt found in waters not coming from these original sources comes from domestic drainage, and indicates that the water is at the present time polluted, or was polluted and has since been purified. By a comparison of the salt contents of any water under examination with the normal chlorine figure for that region, the extent of past or present pollution may be determined.

PHYSIOLOGICAL FUNCTIONS OF COMMON SALT.

Salt always occurs in drainage from animal sources because in all animal economy a certain fairly definite amount of common salt is eaten with the food daily and later expelled from the body in practically the same condition in which it was absorbed. That it plays an important rôle in the blood is indicated by the fact than on an average it constitutes about one-half of the total

blood ash. It is also found that normal gastric juice can not be formed without the presence of salt, and that in many other secretions of the body its presence is probably a necessity.

SALT AS AN INDICATION OF POLLUTION.

The amount of salt in a water is a valuable indication of pollution because of the following facts: The animal body expels the same amount of salt that it absorbs; this salt is unchangeable in the soil and is very soluble in water; it must eventually form a part of the drainage and become mixed with the general run-off of the region in which it is expelled. The average amount of salt entering the drainage of any particular district is so constant for each inhabitant that it has been claimed that the number of people living on a drainage area may be determined with a fair degree of accuracy from the average run-off and the excess of chlorine over the normal.[a] Stearns estimates the chlorine in the run-off of any drainage area not receiving factory waste to be increased about one-tenth of a part per million by every 20 inhabitants per square mile.

SALT IN THE WATERS OF INLAND STATES.

All salt in natural unpolluted waters farther inland than Ohio comes from mineral deposits. The salt winds from the sea have no effect beyond this State, but, unfortunately, west of this State a large proportion of the natural waters are more or less affected by the salt deposits. The underground salt seems to spread over a broad area, and exerts not only a wide but a variable influence over most of the waters. In these inland States, while the "normal chlorine" would be practically zero, the value of the determination of chlorine is in most cases vitiated by the variable quantity of salt from mineral sources. Determinations of chlorine in samples of water taken above and below a city which runs its drainage into the stream examined may give the extent of pollution due to the city sewage, but the waters so far analyzed in the inland States give indications that the question of normal chlorine does not to any great extent enter into sanitary problems.

SALT IN COAST STATE WATERS.

On the other hand, the coast State waters are practically unaffected by this mineral salt, and while very extensive deposits exist, especially in the State of New York, they are in narrow pockets and exert an influence over a very limited area. Except in these pockets the mineral salt has apparently been washed into the sea.

It is found that in the coast States the salt in the natural waters which comes from original sources is practically all brought in by the sea winds, and that a certain normal amount is present in the waters of each locality.

The difference in the normal amount in different localities is due to variations in distance from the seacoast, in the amount of rainfall, in the rate of evaporation, in the amount of protection from ocean winds, and in the direction of the prevailing winds. In spite of the great variety of causes which affect the normal chlorine in natural waters, the normal for any particular region is surprisingly constant.

The chlorine decreases as waters farther and farther inland are tested, so that by connecting with lines on the map localities having the same normal we find that these lines of equal chlorine (isochlors) follow in a general way the

[a] Rept. Massachusetts State Board of Health, 1890, pt. 1, p. 680.

coast lines, and as they extend inland are still more or less parallel to the coast. The distance of these lines from the coast depends chiefly upon the general direction of the wind and the protecting influences of mountains on the coast or of islands near the mainland.

COLLECTION OF SAMPLES.

In order to obtain the normal chlorine lines for any State it is first necessary to collect a large number of analyses for chlorine in waters taken at different seasons over the entire area to be covered. It is evident that near the seacoast, where the variations in chlorine within a limited area are greatest, the largest amount of data must be collected. A large number of samples of water taken from surface and ground sources must be obtained. The pond waters usually give the best results, and careful inspection of the drainage area of such sources gives a good idea of whether or not the water is subject to pollution. Samples for analysis should be chosen as far from human habitation as possible.

SOLUTIONS REQUIRED IN THE ANALYSIS OF WATER FOR CHLORINE.

The following solutions are employed in the analysis of water for chlorine:

Salt solution.—A solution of chemically pure fused salt, containing 1 milligram of chlorine in each cubic centimeter, is made by dissolving 1.648 grams of the fused sodium chloride in 1 liter of distilled water free from chlorine.

Silver-nitrate solution.—Two and one-half grams of crystallized silver nitrate are dissolved in 1 liter of distilled water free from chlorine. To this solution water or strong silver nitrate is added until by actual titration 10 cubic centimeters of it are equal to 5 cubic centimeters of the standard salt solution. One cubic centimeter of this solution is then equal to 0.5 milligram of chlorine.

Potassium-chromate solution.—An indicator solution is made by adding 50 grams of potassium chromate to 1 liter of distilled water and then adding sufficient silver-nitrate solution to precipitate all the chlorine present and turn the precipitate slightly reddish. This is allowed to stand, and by filtering or decanting the clear solution is then obtained.

Emulsion of alumina.—This is made by dissolving 125 grams of potassium or ammonium alum in 1 liter of water and precipitating the alumina from boiling solution by ammonia. After precipitation the alumina must be washed free from chlorine, sulphate, and ammonia by successive treatments, settlings, and decantations with cold distilled water.

METHOD OF PROCEDURE IN THE ANALYSIS OF WATER FOR CHLORINE.

Pour 25 cubic centimeters of the water to be tested into a white porcelain dish. Add about one-half a cubic centimeter of chromate solution and run in standard silver-nitrate solution from a burette until the first faint reddish tint appears. This is more easily noted if for comparison a dish containing the same amount of water and chromate is kept beside the dish in which the test is made.

If 1 or more cubic centimeters of silver nitrate are necessary to reach an end point, the test may be made without evaporation, but if less is required then evaporate 250 cubic centimeters to 25 cubic centimeters volume before making the test. It may at times be necessary to evaporate more than this if the chlorine present is very close to zero in amount.

It is best to always titrate with 25 cubic centimeters of the water. In this case 0.1 cubic centimeter is subtracted from the results as an indicator error.

If more than this amount is used in titration, subtract 0.1 cubic centimeter for each 25 cubic centimeters of the volume of water titrated.

If 250 cubic centimeters of water are taken, the number of cubic centimeters of silver-nitrate solution used to obtain an end point minus 0.1 cubic centimeter multiplied by 2, gives the chlorine in parts per million.

Example: 250 cubic centimeters are evaporated to a volume of 25 cubic centimeters and chromate solution added. In the titration 3.5 cubic centimeters of silver nitrate are used. Then $(3.5 - 0.1) \times 2 = 6.8$. The water, then, contains 6.8 parts per million of chlorine.

If the sample is highly colored and very turbid it may be necessary to clarify it by treating it with an emulsion of alumina. This is best accomplished by bringing the water just to the boiling point, and then adding alumina and shaking the emulsion. In a few minutes the clarified water may be decanted. This is allowed to cool and the required amount is measured out for titration.

OBSERVATIONS ON THE USE OF THE NORMAL CHLORINE MAP.

Having drawn a map of this character for any coast State, we are then able to estimate the pollution in any natural water by the amount of chlorine present over the normal. In some instances it is first necessary to ascertain that the chlorine is not from mineral sources.

It will be seen that the normal chlorine lines are of great practical value, both to the chemist and to the engineer, as they give an index from which may be estimated the sanitary quality of most waters analyzed within the coast States. The chlorine also furnishes information as to the source of deep-seated springs or artesian wells.

While this chlorine in the general run-off is in direct proportion to the population on a drainage area, provided none of the sewage is carried outside of that area, yet waters in this region may have been purified before reaching the source from which they are collected. The chlorine would still be present and it is necessary to find from other tests whether the pollution is present or past.

It will be noted in Mr. Jackson's discussion that the determination of chlorine for the location of isochlors should be made by very precise laboratory methods. In fact, such precision should be used in all cases in which it is necessary to decide whether or not a water in a country where normal chlorine is significant contains chlorides in an amount which corresponds to or approximates a normal for the country from which the water comes. In general water surveys, however, it is necessary to make such nice distinctions only in rare cases. In the determination of chlorides in a water which is to be used for boiler or industrial purposes this refinement is not necessary, and field methods will generally suffice.

FIELD DETERMINATION.

STANDARD SILVER-NITRATE TABLETS.

The Geological Survey proposes to use a method for the rapid determination of chlorides which, from numerous experiments, seems to meet the conditions in a satisfactory manner. In place of the

UNITED STATES GEOLOGICAL SURVEY TABLET CASE.

standard solution of silver nitrate, which must be measured in a burette when applied to a water under examination, there are used tablets of silver nitrate containing a known equivalent of this reagent. These tablets are packed in tubes and carried in a leather case, the details of which are shown in Pl. III. This method of packing is well designed to avoid mechanical agitation of the tablets, which would result in their loss of active equivalent. The tablets are held securely in place by the stoppers, which are sufficiently small to be pushed through the lumen of the tube as fast as the tablets are used. This maintains a constant pressure against the tablets and prevents their agitation.

The manufacture of stable silver-nitrate tablets proved to be somewhat difficult. A number of pharmaceutical experts who were engaged at various times to prepare them failed to produce a tablet which was reasonably stable. Those which are now supplied to the Survey are made by the Kremers-Urban Company, of Milwaukee, Wis., and are of superior quality.

In connection with the determination of chlorides it is necessary to carry into the field only a small bottle of potassium-chromate crystals or solution and a heavy glazed porcelain mortar, together with a pestle of approved design. The tablets are dissolved in a measured quantity of water, a small amount of potassium chromate having first been placed in the solution. The end point is indicated by the change in color in the usual way and the number of tablets of known equivalent indicates the amount of chloride in the water.

This method may be objected to by some chemists because it is generally believed that the results of a chlorine determination made on a water without first evaporating the same are too high. This is apparently true with waters like those of New England, which contain only minute quantities of chlorine, but in the waters of the greater part of the country the chlorides are so high in amount that the error which arises from direct titration is not large enough to be of significance in industrial work.

While the tablets may be manufactured to contain almost any reasonable amount of silver nitrate, it has been found that the most convenient equivalents for general field use are those of approximately 1 and 10 milligrams of chlorine. In all special cases the strength of tablets should be adjusted to suit conditions. As it is practically impossible to manufacture tablets of the exact equivalent desired, it is necessary to determine the strength of each new supply and to make calculations of all field results accordingly.

The following statement includes various tests of a supply of tablets. Each tablet was made up to contain an equivalent of as near 1 milligram of chlorine as possible. The purposes of the tests were

to determine the variation in equivalent of single tablets and the combined equivalent of tablets in sets of 5 and 10, the actual values in milligrams of chlorine being determined by volumetric methods.

Tests to determine variation in silver-nitrate tablets.

[Milligrams.]

Single tablets.		5 tablets.			10 tablets.		
Equivalent of 1 tablet.	Deviation from mean.	Equivalent of 5 tablets.	Mean equivalent of 1 tablet.	Deviation of 1 tablet from mean.	Equivalent of 10 tablets.	Mean equivalent of 1 tablet.	Deviation of 1 tablet from mean.
0.96	−0.045	5.060	1.012	−0.015	10.24	1.024	+0.0055
.95	− .055	5.230	1.046	+ .019	10.15	1.015	− .0085
1.049	+ .044	5.210	1.042	+ .015	10.17	1.017	− .0015
1.062	+ .057	5.110	1.022	− .005	10.18	1.018	− .0005
		5.090	1.018	− .009			
		5.200	1.040	+ .013			
		5.080	1.016	− .011			
		5.110	1.022	− .005			
Mean.	Maximum deviation.	Mean.		Maximum deviation.	Mean.		Maximum deviation.
1.005	+0.057	5.211	1.027	+0.019	10.185	1.018	+0.0055

It will be seen from the above results that the maximum variation in the equivalent of single tablets is 0.057 milligram of chlorine for each tablet. Therefore, considering the maximum variation shown in the single tablets and allowing, for purposes of illustration, that the maximum error may always be present in a determination, it would be necessary to use 18 tablets in a determination in order to reach an error equivalent to 1 milligram of chlorine. The mean value, however, of the single tablet is thoroughly representative of all the tablets tested, the variations lying above and below the mean value equally. It will be seen, further, that when the tablets are used in larger quantities and the combined equivalents of such quantities are compared, the deviations from the mean are considerably less and the maximum deviation is practically negligible. This is shown especially well in the statement of the comparison of the ten tablets. It is therefore apparent that the tablets do not vary by an appreciable amount, and that having established their equivalent by taking the mean of several determinations, such mean can be used in connection with the field determinations of chlorine in natural waters.

PRACTICAL TESTS WITH TABLET METHOD.

Three chloride solutions were made up at random, which, when sted by precise methods, were found to contain 4,280, 12,940, and 372 parts of chlorine per million, respectively. These solutions ere titrated with tablets, and the end points reached in the same anner as that used in the field. The results are set forth in the llowing table:

Tests of silver-nitrate tablets, with solutions of known equivalent.

SOLUTION NO. 1.—CHLORINE, 4,280 PARTS PER MILLION.

Volume of solution.	Number of tablets.	Value of tablets.	Parts chlorine, tablet method.	Deviation from actual value.	Per cent deviation.
c. c.					
22	133.0	1.052	6,350	+2,070	48.4
5	21.0	1.052	4,410	+ 130	3.04
5	21.0	1.052	4,410	+ 130	3.04
25	10.4	10.1	4,200	— 80	1.87
25	10.0 3.0	10.1 1.052	4,160	— 120	2.80
50	20.8	10.1	4,200	— 80	1.87
50	20.0 5.0 1.0	10.1 1.052 .481	4,154	— 126	2.44
					15.06

Mean deviation (six results)=15.06÷6=2.51 per cent.

SOLUTION NO. 2.—CHLORINE 12,940 PARTS PER MILLION.

26	32.25	10.1	12,510	—430	3.32
26	32.0	10.1	12,430	--510	3.94
15	19.5 1.0	10.1 1.052	13,200	+260	2.01
15	18.5 8.0	10.1 1.052	13,020	+ 80	.62
5	64.0	1.052	13,470	+530	4.09
					13.98

Mean deviation=13.98÷5=2.80 per cent.

Tests of silver-nitrate tablets, with solutions of known equivalent—Continued.

SOLUTION NO. 3.—CHLORINE 1,372 PARTS PER MILLION.

Volume of solution.	Number of tablets.	Value of tablets.	Parts chlorine, tablet method.	Deviation from actual value.	Per cent deviation.
c. c.					
50	6.7	10.1	1,353	− 19	1.38
50	6.0 7.0	10.1 1.052	1,358	− 14	1.02
50	6.0 6.0 2.0	10.1 1.052 .481	1,358	− 14	1.02
20	26.0 1.0	1.052 .481	1,392	+ 20	1.46
5	6.0 1.0 2.4	1.052 .481 .253	1,480	+108	7.80
					12.27

Mean deviation=12.27÷5=2.45 per cent.

The first result in the table above set forth is so radically wrong that it is inserted to illustrate a condition which must always be avoided when this method is employed, viz, the use of a large number of tablets. It will be noted that a considerable amount of strong chloride solution was used with tablets of low equivalent, i. e., 1.052 milligrams of chlorine. This made it necessary to use 133 tablets to reach the end point, with a result that is absurd. But 25 and 50 cubic centimeters of the same solution are titrated with the tablets with only a small error when the tablets of larger equivalent, 10.1 milligrams of chlorine, are used. On the whole, the results shown in the above table are very satisfactory, the error involved in the determinations averaging about 2.5 to 3 per cent, which is well within the limits of field work. Indeed, when the method was designed it was believed that an error of 5 per cent would be as small as could be expected.

A very simple way of testing for small amounts of chlorine is afforded by cutting tablets into quarters with a jackknife. Only ordinary care need be used and the quarters may then be taken for analysis without extreme regard to the selection of large or small pieces. The following account of some experiments performed is submitted:

No. 1. Twenty tablets were cut into quarters. Each quarter should precipitate 0.25 milligram of Cl. To 100 cubic centimeters of water (blank = 0.13 cubic centimeter) 1 cubic centimeter of NaCl was

making the actual value of the water = 1.13 milligrams Cl. ıuarters gave no end reaction, but five quarters did. This nent was done fifteen times with the same results. One and ırth tablets are equivalent to 1.25 milligrams Cl.

2. Twenty more tablets were cut up and added as above, except 1 cubic centimeters of NaCl were used, making the value of =1.23 milligrams Cl (blank+0.13 cubic centimeter). Five rs used in eight out of twelve titrations. This shows a varia- quartering of possibly an equivalent of 0.02 milligram Cl, or 't per million, an insignificant amount.

3. Next 1 cubic centimeter of NaCl was used (=1.13 milli- Cl). One whole tablet gave no end reaction, but one whole +one quarter tablet gave a reaction in every case.

4. The same was done with 0.9 cubic centimeter NaCl (=1.03 ·ams Cl). One tablet, no end reaction; 1¼ tablets, end reaction.

5. The same, using 1.2 cubic centimeters NaCl (=1.33 milli- Cl). One tablet, no end reaction,=1 milligram Cl; 1¼ tab- › end reaction,=1.25 milligrams Cl; 1½ tablets gave end reac- 1.50 milligrams Cl.

3, 4, and 5 were each done ten times.

value of these results and their accuracy are shown below:

No.	Milligrams chlorine.	
	Actual content.	Found by titration.
1	1.13	1.25
2	1.23	8 show 1.25 4 show 1.50
3	1.13	1.25
4	1.03	1.25
5	1.33	1.50

; method comes within 0.25 milligram of the amount of chlo- resent, or within 2.5 parts per million of chlorine. This pro- is recommended. If only ordinary care be used in cutting , their value will be within 1 part in a million.

ESTIMATION OF CHLORINE.

ıown amount (about 50 c. c.) of the water to be tested is meas- ıto a glazed porcelain mortar (4 inches diameter) and 5 drops ıssium chromate (5 per cent solution) added.

silver-nitrate tablet is then cut into quarters, using ordinary › get the quarters equal. Whole tablets are added to the water

till near the end point, when quarter tablets are used. The end point is the appearance of the red color of silver chromate.

$\frac{1,000\ nA}{W}$=milligrams per liter of chlorine, when W=cubic centimeters of water used, n = number of tablets used, and A = value of one tablet in milligrams of chlorine. Proper allowance should be finally made for the amount of silver nitrate consumed in the end reaction.

Each tube of $AgNO_3$ tablets is marked with its equivalent of chlorine.

NOTE.—Silver-nitrate tablets should not be handled with the fingers nor exposed to sunlight. Keep all tubes well stoppered.

HARDNESS.

GENERAL STATEMENT.

A hard water is popularly recognized as a water with which it is difficult to obtain a soap lather. Strictly defined, it is that property imparted to water by the carbonates, sulphates, chlorides, and nitrates of calcium and magnesium. Chemical methods for the determination of hardness are not yet well defined; in fact, the whole subject is somewhat chaotic. A method which may be satisfactory for the waters of one part of the United States may be of little value for those of another. Consequently there has developed a rude geographic distribution of methods, each being adapted to the peculiarities of the waters in the regions in which they are used. The result is that comparisons between hardness determinations made in different regions are somewhat uncertain and nearly always unsatisfactory.

The effect of hard water upon the lathering properties of sodium soap—that is, the soap used for laundry and toilet purposes—has been made use of in determining hardness. Indeed, the soap test was the earliest and is still the commonest of all those employed for this purpose. A standard solution of a pure soap, usually a high-grade castile, is standardized against a solution of calcium chloride, the equivalent of which has been determined in terms of calcium carbonate. The details of this process are too familiar to warrant further description. Practically, the principal weakness of the test is the determination of the end point, which is not sharply defined. The sodium salts of oleic, palmitic, and stearic acids which compose a pure soap are definite chemical compounds, and their transformation into calcium and magnesium soaps should follow the usual course of chemical change, and therefore the soap test is not merely a test of the soap-consuming power of water, as maintained by some chemists.

In practice the soap test is limited in its usefulness, and its results are modified by many conditions. A few authorities who have made minute studies of the soap method are impressed with its pos-

sibilities, but the modifications which they suggest are somewhat cumbersome, involve superrefinements, and in the end require so much time that the importance of the results is not commensurate. In those parts of the country where soft waters abound and where it is known that magnesium salts are not abundant the test has great value. Its usefulness is limited in the waters of the Mississippi basin, and it fails entirely when applied to western waters.

FIELD METHOD.

USE OF SODIUM-OLEATE TABLETS.

The soap test has been modified for field use by the substitution of tablets of pure sodium oleate for the soap solution. Sodium oleate can be obtained in pure form and readily divided in tablets, each containing a known amount of the reagent. The tablets used by the Geological Survey in field work are made by the Kremers-Urban Company, of Milwaukee, Wis. They are of three grades, "full," "half," and "quarter," or, as they are usually denoted, "F," "H," and "Q," according to their content of 10, 5, or 2.5 milligrams of sodium oleate, respectively.

In using these tablets, 100 cubic centimeters of the water to be tested are placed in a specially designed bottle (Emil Greiner) having a heavy semispherical bottom. Tablets are then added one at a time and dissolved in the water. This process is greatly hastened by trituration of the tablets in the bottle with a blunt glass rod. After each tablet is dissolved the bottle should be shaken and laid upon its side, and the determination conducted in precisely the same manner as that prescribed in the case of the soap solution. From the number of tablets used and their equivalent the hardness may be determined.

The facility with which this determination may be carried on is largely determined by practice. When first attempted it seems awkward, but after a few trials the operator finds that it can be readily performed. The proper way is to start with the F tablets until near the end point, then apply the H, and finally the Q tablets. This of course may become a method of "trial and error," but the skilled field man will seldom add tablets beyond the end point. The appearance of the lather at various stages is characteristic and affords a guide for the operator. In order to show certain characteristic features in the tablet method for the hardness determination the following results of a test made of a supply of tablets are set forth:

TEST OF SODIUM-OLEATE TABLETS.

For a standard of hardness, 0.2 gram of Iceland spar was dissolved in HCl, evaporated to dryness three times in HCl and twice with water. Finally the residue was dissolved and diluted to one liter

with redistilled water. Five cubic centimeters of this solution of $CaCl_2$ is equivalent to 1 milligram $CaCO_3$.

The tablets used in the work are of three equivalents, and are designated as follows:

One F tablet contains an approximate equivalent of 0.0014 gram calcium carbonate.

One H tablet contains an approximate equivalent of 0.0007 gram calcium carbonate.

One Q tablet contains an approximate equivalent of 0.0003 gram calcium carbonate.

The first test was to determine the amount of sodium-oleate tablet reacted with 100 cubic centimeters distilled water. In the following tabulated statement the sign + denotes a permanent foam or satisfactory end point, while — denotes no end point.

Standardization of sodium-oleate tablets against 100 cubic centimeters distilled water.

F.	H.	Q.	2Q.	$\frac{3Q}{2}$.	$H+\frac{Q}{2}$.
+	+	—	+	—	+
+	+	—	+	—	+
+	+	—	+	—	+
+	+	—	+	—	+
	+	—	+	—	+
	+			—	
	+			—	

Results in the above series of experiments indicate that 100 cubic centimeters distilled water requires about 0.005 grams of sodium oleate.

To reduce this to terms of calcium carbonate experiments were made with 100 cubic centimeters distilled water containing varying amounts of calcium chloride. It was found by repeated trial that where two H tablets were used it required 3.2 cubic centimeters of the $CaCl_2$ solution in 100 cubic centimeters of distilled water to react exactly. Consequently, as the 100 cubic centimeters distilled water required one H tablet, the remaining H tablet was equivalent to the $CaCl_2$. Therefore the distilled water is equivalent in the soap reaction to 3.2 cubic centimeters of $CaCl_2$, or 0.64 milligram $CaCO_3$.

The first experiments in standardizing the tablets were made with the standard $CaCl_2$ solution diluted with 100 cubic centimeters distilled water against one F tablet, with results as follows:

Standardization of sodium-oleate tablet F.

$CaCl_2$ against 1 F tablet.	Result.
c.c.	
3.0	Foam.
3.5	Foam.
3.6	Foam.
3.7	Foam.
3.7	Foam.
3.7	Foam.
3.7	Foam.
3.8	No foam.
3.8	No foam.
4.0	No foam.

From the above it appears that one F tablet is equivalent to 3.7 cubic centimeters $CaCl_2$ solution with 100 cubic centimeters distilled water, or actually equivalent to 6.9 cubic centimeters (3.7+3.2 cubic centimeters), which expressed in terms of $CaCO_3$ is equal to 1.38 milligrams.

Using seven F tablets in 100 cubic centimeters distilled water against different amounts of the $CaCl_2$ solution the following results were reported:

$CaCl_2$ against 7 F tablets.	Result.
c. c.	
41.7	Foam.
41.5	Foam.
42.5	Foam.
44.9	Foam.
45.0	Foam.
45.9	No foam.
46.0	No foam.

From the above results it appears that the end point is practically reached with 45 cubic centimeters $CaCl_2$ solution. With the amount for 100 cubic centimeters distilled water added, seven tablets are therefore equivalent to 48.2 cubic centimeters $CaCl_2$, or 9.64 milligrams $CaCO_3$. This allows for one tablet an equivalent of 1.37 milligrams $CaCO_3$, which agrees with the previous determinations within the limit of experimental error.

Experiments were made with various combinations of tablet follows:

$CaCl_2$.	Tablets (number and value).	Result.
c. c.		
3.2	4 Q	No foam.
3.2	5 Q	Foam.
3.0	5 Q	Foam.
3.0	5 Q	Foam.
2.8	4 Q	Foam.
2.9	4 Q	Foam.
45.0	7 F	Foam.
45.9	7 F	No foam.
45.9	7 F + 1 Q	Foam.
45.0	14 H	No foam.
45.0	15 H	Foam.
45.0	6 F + 2 H	Foam.
45.0	6 F + 2 H	Foam.

Analyzing the results above given we have:

1.

$CaCl_2$+100 c. c. distilled water.	Tablets (number and value).	Result.
c. c.		
3.2	4 Q	No foam.
3.2	5 Q	Foam.
3.0	5 Q	Foam.
2.8	4 Q	Foam.
2.9	4 Q	Foam.

Therefore four Q tablets are equivalent to an amount of CaC lying between 1.28 milligrams and 1.22 milligrams, or one Q tablet an amount lying between 0.32 and 0.30. Using either as the valu the error will not be significant. 0.31 milligram is probably the mo accurate factor.

2.

$CaCl_2$+100 c. c. distilled water.	Tablets (number and value).	Result.
c. c.		
45.0	7 F	Foam.
45.9	7 F	No foam.
45.9	7 F+1 Q	Foam.

Therefore seven F tablets are equivalent to an amount of $CaCO_3$ lying between 9.82 and 9.64 milligrams, or one tablet to an amount lying between 1.40 and 1.38 milligrams. The error introduced if either 1.40 or 1.38 is used as a factor will be less than $\frac{Q}{7}$ and therefore insignificant.

3.

$CaCl_2$+100 c. c. distilled water.	Tablets (number and value).	Result.
c. c.		
45	14 H	No foam.
45	15 H	Foam.
45	6 F+2 H	Foam.

Therefore the equivalent of 9.64 milligrams $CaCO_3$ lies between the value of 14 and 15 H tablets, or one tablet is equivalent to an amount of $CaCO_3$ between 0.69 and 0.64 milligram. But from the third experiment it is seen that two H tablets are equivalent to 1.36 milligrams (9.64—[6×1.38]), or one tablet to 0.68 milligram.

ESTIMATION OF HARDNESS.

The directions for using these tablets should be followed absolutely. The end-point foam should be permanent for at least five minutes, the bottle lying upon its side. The smallest number of tablets possible should be used; for example, if the hardness of a water is 120 parts per million on direct titration without correction, the best procedure assuming the given value of the tablets used would be as follows:

	Milligrams $CaCO_3$.
8 F tablets equivalent to	11.04
1 H tablet equivalent to	.68
1 Q tablet equivalent to	.31
Total	12.03
Subtracting 0.64 milligram $CaCO_3$ for distilled water	.64
Hardness expressed by tablets	11.39
Or in parts per million	113.9

In this case the error would be equivalent to 0.03 milligrams $CaCO_3$, an amount unimportant in practical work.

The end point can be approached in the manner above described after the operator has had a short experience with the method. The comparative permanence of the preliminary foam pellicles which do not remain unbroken for the entire five minutes is a guide.

HARDENING CONSTITUENTS.

CLASSES.

It is customary to distinguish between temporary and permanent hardness. Temporary hardness is due to the carbonates (and bicarbonates) of calcium and magnesium. Calcium and magnesium carbonates are not readily soluble in water unless accompanied by carbon dioxide. Under such circumstances it is supposed that the carbonates become bicarbonates, although the bicarbonates of these two elements have never been isolated. When waters containing calcium and magnesium bicarbonates are boiled the carbon dioxide is driven off and the normal carbonates of calcium and magnesium are precipitated. Therefore, the properties which they impart to the water are designated temporary hardness. Permanent hardness, on the other hand, is that property which is imparted to waters by the sulphates, chlorides, and nitrates of the alkali earths. They are not precipitated by ordinary boiling, and therefore their effects are regarded as permanent. The usual method of determining temporary and permanent hardness by the soap test consists in making the test on a sample of water before boiling, and another on a similar sample after boiling; the difference in the two results representing the temporary hardness.

Temporary and permanent hardness are often expressed as alkalinity and incrusting constituents, respectively, and it is common to see, even in analytical reports of well-informed chemists, the expression "alkalinity or temporary hardness." This expression is misleading. It is approximately correct when the waters of New England and certain other portions of the country are referred to, but as a general statement concerning the majority of waters nothing could be more inaccurate. There are abundant instances in which waters are alkaline to an extraordinary degree, and yet are widely known as soft waters, giving little or no reaction with the soap test. The alkalinity in such cases is due to the carbonates of sodium and potassium, which, while they impart a truly alkaline reaction, have no hardening effect. The majority of the waters of the United States contain alkali carbonates, and therefore any interpretation of alkalinity as being equivalent to temporary hardness with such waters is erroneous.

If the alkalinity found in a water is the result of the carbonates of the alkali-earth elements, its industrial significance is considerably different from that of the carbonates of the alkalies. For example, calcium carbonate forms soft scale when used in boilers, while sodium carbonate forms no scale, but presents a much less important difficulty, that of foaming. If, however, a water containing calcium carbonate were used for irrigation purposes, it

would not damage crops unless it were present in extremely high proportions—higher, in fact, than it is almost ever found in nature. On the other hand, a small amount of sodium carbonate is destructive to crops. It is as desirable to know whether the sulphates and chlorides which are found in the water are of the alkali earths or the alkalies, for they present variations in usefulness with reference to industries similar to those above described in the case of the carbonates.

It has been the endeavor of the Geological Survey to so modify the methods by which the various determinations of the hardening constituents of water may be made that they can be used in the field. These methods are set forth in subsequent pages. They do not include all of the determinations desirable for some classes of work, but sufficient to allow of a very comprehensive interpretation concerning the quality of any water under investigation.

CARBONATES.

The determination of alkalinity or carbonates is a simple volumetric process. It requires only a standard solution of an acid, preferably a mineral acid, with accurate means for measuring the same, and a proper indicator solution. On account of the carbon dioxide set free by the determination, methyl orange is the indicator in commonest use. The objections already cited to carrying standard solutions and burettes in the field led to an attempt to adopt an acid which could be preserved in tablet form. Many organic acids were tried, but is was found that they were either too weak to afford a definite end point or were of so deliquescent a character that they could not be made to form stable tablets. It was finally decided to adopt the use of sodium acid sulphate. Tablets made from this reagent are easily regulated in equivalent and are of an extremely stable nature. The results which can be procured through their use are very satisfactory.

TESTS OF SODIUM ACID-SULPHATE TABLETS.

For use in titrating against sodium acid-sulphate tablets a fiftieth normal solution of sodium carbonate was made, in which each cubic centimeter equals 1.06 milligram $NaCO_3$. Six sets of five sodium acid-sulphate tablets each were then dissolved in 50 cubic centimeters of distilled water and each solution was titrated with the standard sodium carbonate. The results of these titrations are shown in the following table:

Standardization of sodium acid-sulphate tablets.

$NaHSO_4$.	Na_2CO_3.	Value of 1 tablet.
c. c.	c. c.	$MgCaCO_3$.
10.60	2.15	2.03
10.15	2.05	2.02
10.85	2.20	2.03
10.30	2.10	2.04
10.10	2.05	2.03
10.10	2.05	2.03

Assuming these final reactions,

$$Na_2CO_3 + 2NaHSO_4 = 2Na_2SO_4 + H_2O + CO_2,$$

$$\text{and } CaCO_3 + 2NaHSO_4 = CaSO_4 + H_2O + CO_2 + Na_2SO_4,$$

then for the expression of the value of our tablet in milligrams of $CaCO_3$ we have the following proportion:

$$\frac{Na_2CO_3}{CaCO_3} = \frac{106}{100}.$$

The experiments above described were made with solutions of the acid-sulphate tablets, and the results show the constancy of the reaction between the normal carbonate and the sulphate. They do not show, however, the variations which would occur in the practical use of the tablets applied directly to the alkaline solution, as would be done in the field. Therefore the following tests are submitted to show the deviations which may arise in successive tablets or successive sets of tablets. The tablets used were marked "Lot 715, sodium acid-sulphate equivalent to 1.995 milligrams calcium carbonate." These tablets had been in stock for several months, had received some rough handling, and were in poor condition. In fact, they represented the most unfavorable conditions that might be supposed to occur in connection with the field use of tablets, and the variations which are shown may be accepted as the extreme variations which are likely to occur in common use.

In testing and standardizing the sodium acid-sulphate tablets normal solutions of sulphuric acid and sodium carbonate were used. Tests were made as follows:

Solutions of unknown strength of sodium carbonate were made up and the alkalinity was determined volumetrically with standard sulphuric acid solution. Following this, determinations of the same unknown solutions were made with the tablets. Varying amounts of the solution were used, with a corresponding variation in the number of tablets.

parative determinations of alkalinity in carbonate solutions with standard sulphuric-acid and sodium acid-sulphate tablets.

BONATE SOLUTION NO. 1.—ALKALINITY, 5,764 PARTS PER MILLION IN TERMS OF CALCIUM CARBONATE.

Amount of solution.	Number of tablets.	Parts per million.	Deviation in parts per million.	Per cent deviation.
c. c.				
1.9	5	5,225	—539	9.3
3.5	10	5,674	— 90	1.56
7.0	20	5,674	— 90	1.56
11.0	32	5,726	— 38	.66
10.5	30			
17.5	50	5,674	— 90	1.56
46.5	135	5,767	+ 3	.05

BONATE SOLUTION NO. 2.—ALKALINITY, 2,312 PARTS PER MILLION IN TERMS OF CALCIUM CARBONATE.

4.5	5	2,207	—105	4.55
10.0	12	2,383	+ 71	3.1
15.0	18	2,384	+ 72	3.1
21.0	25			
19.0	23			
25.5	30	2,359	+ 47	2.0
25.0	30			
51.0	60	2,328	+ 14	.61
50.5	59			

'he figures of the above tables show that when a large number tablets are used to determine alkalinity the results are more rly correct than when a few are used. This is especially notice- ɜ in the first entries in the two tables, where the small amount the alkaline solution used requires only five tablets. The error each of these cases is larger than is permissible even in field 'k. In the remainder of the tests, however, the variation is not iciently great to be appreciable, especially in the weaker car- ate solutions, where it is shown that the use of a larger number tablets involves a minimum error. This suggests that in con- tion with the field determination of carbonates it is advisable, ɜrever waters of a low alkalinity are tested, to use a large amount the water in order that a large number of tablets can be used to tralize the alkalinity, and thereby avoid the error arising from variation which occurs in the single tablets.

ESTIMATION OF ALKALINITY.

Measure 100 cubic centimeters of water to be tested into a glazed porcelain mortar (4 inches diameter). Add two drops methyl-orange indicator. Add $NaHSO_4$ tablets till an acid reaction is reached. Then add some of the original water that is being tested, drop by drop, till an alkaline reaction is exactly reached. Measure the liquid in the mortar and to the amount of the reading add 1 cubic centimeter for the wetted interior of the dish. The following formula is convenient for use in making calculations of alkalinity:

$$\frac{1{,}000\ n\ A}{W} \text{ equals milligram per liter of } CaCO_3.$$

When W equals cubic centimeter of water used;
n equals number tablets used;
A equals value of 1 tablet in milligrams of $CaCO_3$.

Each consignment of tablets is marked with its value in equivalent of $CaCO_3$.

NORMAL AND ACID CARBONATES.

It is nearly always of value to determine the proportion of normal and acid carbonates in a water, for it affords a fairly good index to the character of the base with which the carbon dioxide is united. It is a generally accepted idea that the carbonates of the alkaline-earth metals are, when in solution in water, in the form of bicarbonates. For the general purposes of field work it may be considered that all bicarbonates occurring in natural waters are alkaline-earth carbonates and may conveniently be calculated as $CaCO_3$. All normal carbonates, on the other hand, must be alkali carbonates, conveniently calculated as Na_2CO_3. This generalization is not uniformly true, especially in certain classes of western waters. It has been plainly shown, by the work of Messrs. Frank K. Cameron and Lyman J. Briggs, of the Bureau of Soils, United States Department of Agriculture, that there is considerable complexity in the occurrence and equilibrium of carbonates and bicarbonates in waters. There are, however, few practical water problems occurring outside of the alkali-desert regions in which the interpretation of bicarbonates as alkaline-earth carbonates and normal carbonates as alkali carbonates would lead to erroneous results. The field men of the United States Geological Survey are therefore instructed to report bicarbonates as $CaCO_3$ and normal carbonates as Na_2CO_3, in the absence of data which will allow of other interpretations.

The method of determining carbonates and bicarbonates in aqueous solution is discussed by Mr. Frank K. Cameron, chemist of the Bureau of Soils, in Bulletin No. 18 of the United States Department of Agriculture, Bureau of Soils, pages 77–89. The method depends upon the

fact that while phenolphthalein reacts with the normal carbonates of the alkali and alkaline-earth metals and not with the bicarbonates, methyl orange reacts with either. The water under investigation is titrated with a standard solution of potassium acid sulphate, using phenolphthalein as an indicator, the first end point being the complete disappearance of the red color. Methyl orange is then added to the solution, and the titration is continued with the same standard until a pink acid reaction is obtained. The amount of standard solution used to reach the first end point is a measure of the amount of normal carbonates, while the total amount used in securing both end points, less twice that for the first end point, is a measure of the bicarbonates.

The reaction taking place before and up to the total neutralization of the phenolphthalein is a conversion of carbonates into bicarbonates and can probably be expressed as follows:

$$2KHSO_4+2Na_2CO_3=Na_2SO_4+K_2SO_4+2NaHCO_3$$

or

$$2KHSO_4+2MgCO_3=MgSO_4+K_2SO_4+Mg(HCO_3)_2.$$

The neutralization of bicarbonates probably takes place in this manner:

$$2KHSO_4+2NaHCO_3=Na_2SO_4+K_2SO_4+2H_2O+2CO_2$$

or

$$2KHSO_4+Mg(HCO_3)_2=MgSO_4+K_2SO_4+2H_2O+2CO_2.$$

It is evident that when the end point with phenolphthalein has been reached there remains as a product of the first reaction, in addition to the bicarbonates originally present, an amount of bicarbonates equal in reacting power to the reaction shown by the phenolphthalein. In other words, double the amount of potassium acid sulphate required to convert the carbonates to bicarbonates, and so destroy the color of the phenolphthalein, is necessary to completely neutralize the normal carbonates as indicated by methyl orange. This must be taken into consideration in computing the results from the titration.

Inasmuch as the reactions taking place when sodium acid sulphate is used must be similar to those with the use of potassium acid sulphate, there is no reason to believe that the tablets now in use in this division may not be substituted for the standard solution suggested by Mr. Cameron. Experiments have been made to determine the accuracy of the results obtainable and are discussed in the following paragraphs.

An unknown amount of thoroughly fused Kahlbaum's sodium bicarbonate was dissolved in distilled water that had previously been boiled to drive out carbonic acid. Twenty-five cubic centimeters

this solution, which should contain only sodium carbonate, was tested by adding phenolphthalein, triturating and dissolving standard tablets of sodium acid sulphate till decolorized, adding methyl orange, and continuing the trituration until the methyl-orange end point was reached. Another equal portion of the solution was tested by adding methyl orange alone and dissolving tablets until the end point was reached. The results in the two cases were as follows:

1. Necessary for phenolphthalein end point	9 tablets.
Excess necessary for methyl-orange end point	9 tablets.
2. Total necessary for methyl-orange end point	18 tablets.

Two solutions were then made, one similar to the first, of sodium carbonate in boiled distilled water, the other of supposedly pure Kahlbaum's sodium bicarbonate in distilled water, also boiled. These were tested by solution of tablets, using first phenolphthalein and then methyl orange as an indicator, as in the first case.

Sodium carbonate solution	25 cubic centimeters.
Necessary for phenolphthalein end point	27 tablets.
Necessary excess for methyl-orange end point	27 tablets.
Sodium bicarbonate solution	25 cubic centimeters.
Necessary for phenolphthalein end point	15 tablets.
Necessary excess for methyl-orange end point	57 tablets.

It is evident that the solution of bicarbonate was impure, 30 tablets out of a total of 72 being required for the neutralization of the normal carbonate. A mixture of these two solutions was then made, as follows:

	Cubic centimeters.
Sodium carbonate solution	100
Solution containing bicarbonate	100
Distilled water (boiled)	200

It is evident that the number of tablets required by this solution, if the method is reliable, will be equal to one-fourth of the sum of all the tablets used to neutralize the two original solutions, 25 cubic centimeters being taken in each case. This should be true, not only of the whole determination, but of each part. Tests made of the mixture resulted as follows:

Necessary for phenolphthalein end point	10½ tablets.
Necessary excess for methyl-orange end point	21 tablets.

Inspection of these figures and comparison with those preceding indicate that, in so far as it is possible to judge under the conditions, the method is accurate and reliable.

To make the determination, measure a convenient quantity of the water to be tested into a porcelain mortar and add 4 drops of phenolphthalein (1 per cent). Triturate the standard $NaHSO_4$ tablets in the mortar, one at a time, until the color disappears. Note the

number of tablets and then add 4 drops of methyl orange (1 per cent). Continue the titration with the tablets until the orange color of the solution changes to a faint pink. Then note the total number of tablets used in both titrations. The equivalent of the sodium acid-sulphate tablets is usually given in terms of calcium carbonate. Therefore the amount of bicarbonates in the water may be calculated directly from this valuation. In order to calculate the normal carbonates as Na_2CO_3, it will be necessary to multiply the valuation of the sodium-sulphate tablets given by 1.06, the conversion factor of $CaCO_3$ to Na_2CO_3.

For computation of the normal carbonates in parts per million, double the number of tablets used for the decolorization of phenolphthalein, multiply by the equivalent of each tablet in milligrams Na_2CO_3. Then multiply this product by 1,000 and divide the whole by the number of cubic centimeters of the sample tested. To find bicarbonates in parts per million, subtract from the total number of tablets used in the two titrations twice the number required for the phenolphthalein end point and multiply this difference by the equivalent of each tablet in terms of calcium carbonate. Then multiply this product by 1,000 and divide by the number of cubic centimeters of water tested.

For the convenient expression of the above in formulas, assume the following symbols:

A = equivalent of $NaHSO_4$ tablets in terms of milligrams of $CaCO_3$.
B = equivalent of $NaHSO_4$ tablets in terms of milligrams of Na_2CO_3.

The conversion factor being 1.06, we have

$$A = \frac{B}{1.06} \text{ or } B = 1.06A.$$

n = number of tablets used to reach first or phenolphthalein end point.
N = number of tablets used to reach second or methyl-orange end point.
W = amount in cubic centimeters of water tested.

Then for the determination of normal carbonates we have the formula

$$\frac{2{,}000nB}{W}$$

and for the determination of bicarbonates

$$\frac{1{,}000(N-2n)A}{W}$$

The results of the two above equations will be the expression of parts per million.

SULPHATES.

Water generally contains either one or more of the sulphates of sodium, potassium, calcium, magnesium, and iron. If present in minute amounts the effect of any or all of them is negligible, but if

they appear in large proportions they do damage in every branch of science or industry in which it is necessary to use water. Calcium, magnesium, and iron sulphates damage boilers, textiles, soaps, malt liquors, paper, and many other manufactured products, while they render water undesirable for domestic purposes. The sulphates of sodium and potassium are troublesome in boilers, and damage crops when water containing large amounts is used for irrigation. A knowledge of the amount of sulphates in a water is of great importance.

The determination of sulphates, as it is usually performed in the laboratory, is a slow, laborious, and expensive process. A field method has, however, been devised by which the sulphates can be determined in a few minutes and with a degree of accuracy sufficient for all practical purposes. The determination involves the use of the Jackson turbidimeter, described on previous pages. In the following paragraphs the determination of sulphates is described by the originator of the method, Mr. Daniel D. Jackson:

DETERMINATION BY TURBIDIMETER.

Knowledge of the amount of sulphates in a water to be used for industrial purposes is especially important. The scale which is most troublesome to remove from boilers is produced by the precipitation of sulphate of lime. If the amount of sulphate is considerable the determination of lime may be made by the turbidimeter with a fair degree of accuracy. The method is as follows:

To 100 cubic centimeters of water to be tested add 1 cubic centimeter of hydrochloric acid (1–1) and 1 gram of solid barium-chloride crystals. If the amount of sulphate is low, 200 or 300 cubic centimeters of water must be treated in order to fill the longer tube employed. In this case add 1 cubic centimeter of acid and 1 gram of barium chloride for each 100 cubic centimeters of water taken.

The mixture should be allowed to stand for ten minutes, and in this time it should be frequently shaken. It is best to employ a bottle for this purpose. Treating the water in the cold with solid barium chloride causes the barium sulphate to be precipitated in a finely divided state, and the turbidity produced may then be read by either the candle or the electric turbidimeter.

In the lower part of the tube the end point is taken when the hazy cross of light disappears. This is a higher reading than the point where the sharp cross disappears. Higher up in the tube there is no hazy cross of light, and the end point is the disappearance of the sharp cross of light. When this point is obtained, remove the glass tube and find the depth of the liquid (using the bottom of the meniscus in reading). Refer this reading to the accompanying table to obtain the parts per million or grains per gallon of sulphate present.

The readings of these instruments are only to a very slight extent affected by the amount of light used, so that a fairly wide variation in this respect gives little or no error in the result. This is also true with variations in the color of different natural waters. The reason for this lies in the fact that the end point is not to any great extent dependent upon the amount of light cut out, but to the complete covering up of the image of light by the particles in suspension. It is surprising to find that the interposition of disks, even of highly colored glass, produces little or no effect upon the end point.

In using the electric turbidimeter, if the image becomes perceptibly dim the attery is replaced by a fresh one, but if the analyst is careful to keep the light ırned off except when actually making readings the batteries will last for a con- derable period of time. Fresh electric bulbs and batteries may be obtained 'om the Howard Electric Novelty Company, 221–227 Canal street, New York ity, or 183 Lake street, Chicago. If any parts of the instrument are lost or roken they may be replaced by Baker & Fox, 83 Schermerhorn street, Brook- 'n, N. Y.

able for converting readings in depths by the turbidimeter into parts per million or grains per gallon of sulphate.

Reading in centimeters.	Parts per million, SO_3.	Grains per United States gallon, SO_3.	Reading in centimeters.	Parts per million, SO_3.	Grains per United States gallon, SO_3.
1.0	522	30.5	3.9	144	8.4
1.1	478	28.0	4.0	140	8.2
1.2	442	25.8	4.1	137	8.0
1.3	410	24.0	4.2	133	7.8
1.4	383	22.4	4.3	131	7.7
1.5	359	21.0	4.4	128	7.5
1.6	338	19.8	4.5	125	7.3
1.7	319	18.6	4.6	122	7.1
1.8	302	17.7	4.7	119	7.0
1.9	287	16.8	4.8	117	6.8
2.0	273	16.0	4.9	115	6.7
2.1	261	15.3	5.0	113	6.6
2.2	250	14.6	5.1	110	6.4
2.3	239	14.0	5.2	108	6.3
2.4	230	13.5	5.3	106	6.2
2.5	221	12.9	5.4	104	6.0
2.6	213	12.4	5.5	103	6.0
2.7	205	12.0	5.6	101	5.9
2.8	198	11.6	5.7	99	5.8
2.9	191	11.2	5.8	97	5.7
3.0	185	10.8	5.9	96	5.6
3.1	179	10.5	6.0	94	5.5
3.2	173	10.1	6.1	93	5.4
3.3	168	9.8	6.2	91	5.3
3.4	164	9.6	6.3	90	5.2
3.5	159	9.3	6.4	88	5.1
3.6	155	9.1	6.5	87	5.1
3.7	151	8.8	6.6	86	5.0
3.8	147	8.6	6.7	84	4.9

Table for converting readings in depths by the turbidimeter into parts per million or grains per gallon of sulphate—Continued.

Reading in centimeters.	Parts per million, SO_3.	Grains per United States gallon, SO_3.	Reading in centimeters.	Parts per million, SO_3.	Grains per United States gallon, SO_3.
6.8	83	4.9	12.4	46	2.7
6.9	82	4.8	12.6	45	2.6
7.0	81	4.8	12.8	44	2.6
7.1	80	4.7	13.0	43	2.5
7.2	79	4.7	13.5	42	2.5
7.3	78	4.6	14.0	41	2.4
7.4	77	4.5	14.5	39	2.3
7.5	76	4.4	15.0	38	2.3
7.6	75	4.4	15.5	37	2.2
7.7	74	4.3	16.0	36	2.1
7.8	73	4.3	16.5	35	2.0
7.9	72	4.2	17.0	34	2.0
8.0	71	4.2	17.5	33	1.9
8.1	70	4.1	18.0	32	1.9
8.2	69	4.0	18.5	31	1.8
8.3	68	4.0	19.0	30	1.8
8.5	67	3.9	20.0	29	1.7
8.6	66	3.9	21.0	28	1.7
8.7	65	3.8	22.0	27	1.6
8.8	64	3.8	22.5	26	1.6
9.0	63	3.7	23.0	25	1.5
9.1	62	3.7	24.0	24	1.4
9.3	61	3.6	25.0	23	1.3
9.5	60	3.6	26.5	22	1.3
9.7	59	3.5	28.0	21	1.2
9.8	58	3.4	29.0	20	1.2
10.0	57	3.3	31.0	19	1.1
10.2	56	3.3	33.0	18	1.1
10.4	55	3.2	35.0	17	1.0
10.6	54	3.2	37.5	16	1.0
10.8	53	3.1	40.0	15	.9
11.0	52	3.1	43.0	14	.9
11.2	51	3.0	46.5	13	.8
11.4	50	3.0	50.0	12	.7
11.6	49	2.9	55.5	11	.6
11.8	48	2.8	62.0	10	.6
12.0	47	2.7	68.0	9	.5

PRECAUTIONS IN USE OF INSTRUMENT.

1. The same care should be taken as in measuring turbidity to have the turbidimeter in good running order. 2. Always shake the solution until all the barium chloride is dissolved. Otherwise a flaky precipitate may be obtained. 3. Since the barium-sulphate precipitate is very heavy, the solution should be mixed frequently by pouring and shaking while readings are being made. 4. Only sufficient hydrochloric acid should be added to make the water acid.

CALCIUM.

The determination of calcium is made by means of the turbidimeter, the method being similar to that described in the chapter on sulphates. It is the latest, and therefore the least known, of all the determinations here described. While the results which have been reached by this method appear to be satisfactory, no particular plan has yet been offered to determine certain necessary facts with reference to the behavior of precipitated calcium oxalate. The method depends upon the turbidity produced by the precipitation of calcium oxalate upon the addition of ammonium oxalate to the water under investigation. Whether or not the variations which occur in the character of this precipitate under different conditions are sufficient to affect appreciably the degree of turbidity produced is a matter which is yet to receive attention.

The test is made in the following manner: To 100 cubic centimeters of the water to be tested add a few drops of ammonium hydroxide, NH_4OH. The amount added should be barely sufficient to impart to the water a perceptible ammoniacal odor. Then add crystals of ammonium oxalate. The amount of crystals to be added depends, of course, upon the amount of lime in the water. As this is yet undetermined, care should be taken to add an excess of ammonium oxalate. Mix thoroughly and allow the solution to stand for ten or fifteen minutes. Then determine the turbidity with the Jackson turbidimeter precisely as described in previous pages in the case of sulphates. and state the amount of calcium according to the table given below.

The treatment above described will precipitate materials other than calcium, but they are usually in so small a proportion in natural waters that they do not often give trouble. The most frequent complication arises from the precipitation of magnesium on the addition of ammonia. If the precipitate is sufficient in amount to materially affect the degree of turbidity it should be filtered before the addition of ammonium oxalate.

The table given below for the determination of calcium is less satisfactory than that for sulphates, and it will probably be found that corrections must be made as future experience dictates.

Table for determining calcium with Jackson's turbidimeter.

Reading in centimeters.	Parts per million.	Reading in centimeters.	Parts per million.	Reading in centimeters.	Parts per million.	Reading in centimeters.	Parts per million.
1.0	1,150	4.0	167	7.0	80	10.0	53
1.1	1,000	4.1	162	7.1	78	10.2	52
1.2	890	4.2	156	7.2	77	10.4	51
1.3	795	4.3	151	7.3	76	10.6	50
1.4	715	4.4	146	7.4	74	10.8	49
1.5	650	4.5	142	7.5	73	11.0	48
1.6	595	4.6	137	7.6	72	11.2	47
1.7	550	4.7	133	7.7	71	11.4	46
1.8	505	4.8	130	7.8	70	11.7	45
1.9	470	4.9	126	7.9	69	11.9	44
2.0	435	5.0	123	8.0	68	12.2	43
2.1	410	5.1	119	8.1	67	12.4	42
2.2	380	5.2	116	8.2	66	12.7	41
2.3	360	5.3	113	8.3	65	13.0	40
2.4	340	5.4	110	8.4	64	13.3	39
2.5	320	5.5	107	8.5	64	13.7	38
2.6	305	5.6	105	8.6	63	14.0	37
2.7	288	5.7	102	8.7	62	14.4	36
2.8	274	5.8	100	8.8	61	14.8	35
2.9	261	5.9	98	8.9	60	15.3	34
3.0	248	6.0	96	9.0	60	15.7	33
3.1	238	6.1	94	9.1	59	16.2	32
3.2	228	6.2	92	9.2	58	16.7	31
3.3	218	6.3	90	9.3	57	17.3	30
3.4	209	6.4	88	9.4	57	17.9	29
3.5	200	6.5	87	9.5	56	18.5	28
3.6	194	6.6	85	9.6	55	19.2	27
3.7	186	6.7	84	9.7	55	20.0	26
3.8	179	6.8	82	9.8	54	21.7	24
3.9	173	6.9	81	9.9	54	22.7	23

INSTRUMENTS AND REAGENTS.

The field case (see Pl. IV) contains the instruments and reagents described below:

1. A Berkfeld army filter for removing suspended matter from water under investigation. The porous stone in this filter should

UNITED STATES GEOLOGICAL SURVEY FIELD CASE.

removed from the tube frequently and thoroughly cleansed with small stiff brush provided for this purpose. If it is desired to ure sterile water, or if the only water available is known to be lluted and a supply for drinking purposes is desired, the filter stone uld be boiled or baked frequently. Watch the filter stone closely cracks and imperfections. When water is pumped through the er, care should be taken that the suction end does not rest on d or mud; such materials, if drawn into the buckets of the pump, troublesome and materially shorten the term of usefulness of the er.

2. One or more leather cases containing tubes of reagent tablets. e equivalent of each tablet of the various reagents should be noted a slip pasted upon the inside of the case.

The tablets are packed in tubes to prevent mechanical agitation. is is highly important, because if the tablets are loosely packed oss of active chemical reagent is inevitable. Tablets which show ns of extraordinary wear should be rejected. In using a tube e of the cork stoppers should be removed and the tablets poured t as needed. When the end point is reached the cork should be laced and the stoppers in the opposite end of the tube should be shed through the lumen until the tablets remaining in the tube are jected against the opposite stopper, thus holding them securely.

Sodium-oleate tablets are packed in unmarked transparent glass es. Two grades of silver-nitrate tablets are usually issued. The es containing tablets of the higher equivalent have a cross etched the glass, while those with the lower equivalent are etched with ingle transverse line. The sodium acid-sulphate tablets are packed transparent glass tubes, upon each of which is etched the symbol HSO_4.

3. One case containing four aluminum tubes for natural color and iron determinations. There will also be provided brown-glass ks for the color determination or red-glass ones for the iron, or th. The equivalent of each disk in terms of parts per million is raved on the aluminum rim.

4. One Jackson candle or electric turbidimeter with two graduated linders for same. An extra electric bulb, a ground-glass disk, a ss cross disk, a standard English candle, and a dry battery will be vided with each turbidimeter. The field observer should not use y dry battery which has been in his possession over sixty days, espective of the intensity of the light produced by it. Candles er than the standard English sperm should not be used.

The candle turbidimeter should be used in preference to the electric enever possible, as the former is the more steady instrument and ures uniformity of results. If, however, it is necessary to make

determinations in exposed places when the wind is blowing, the electric turbidimeter must be used, as the slightest flickering of the candle flame will introduce errors in the determinations. Whenever possible, water samples should be carried to a convenient shelter and assayed.

5. Seven special dropping bottles containing the following reagents: Concentrated nitric acid (HNO_3); concentrated hydrochloric acid (HCl); concentrated ammonium hydroxide (NH_4OH); two per cent solution of potassium sulphocyanide ($KCNS$); five per cent solution of potassium chromate (K_2CrO_4); one per cent solution of phenolphthalein; one-tenth per cent solution of methyl orange.

Care should be taken to close the stoppers in these dropping bottles where they are packed in the cases.

6. Two salt-mouth bottles containing pure crystals of barium chloride and ammonium oxalate.

All bottles containing chemicals have etched labels, except the indicators, the colors and odors of which are sufficient for identification.

7. One heavily glazed porcelain mortar and pestle.

8. One round-bottom glass bottle, with glass pestle, for hardness determination.

9. One small horn spoon for handling crystals noted in section 6.

10. One 5 c. c. pipette in case for general use in measuring small amounts of liquid.

11. One centigrade thermometer in brass case.

12. One loose-leaf notebook. This notebook is made up of printed cards, with every alternate leaf a blank.

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PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 151.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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Correspondence should be addressed to

THE DIRECTOR,
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WASHINGTON, D. C.

OCTOBER, 1905.

Water-Supply and Irrigation Paper No. 152 Series L, Quality of Water, 12

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

A REVIEW

OF THE

LAWS FORBIDDING POLLUTION OF INLAND WATERS IN THE UNITED STATES

SECOND EDITION

By EDWIN B. GOODELL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., August 17, 1905.

SIR: I transmit herewith a manscript entitled "A Review of the Laws Forbidding Pollution of Inland Waters of the United States," prepared by Edwin B. Goodell, and request that it be published as a water-supply and irrigation paper. This paper is a second edition of Water-Supply Paper No. 103, published last year. The subject-matter has been brought to date by the incorporation of the statutes passed since the first edition was prepared, and the section on pollution under the common law has been amplified to include the arid States and Territories.

One of the important features involved in the determination of the water supplies of the United States and the preparation of reports upon the best methods of utilizing water resources is the character of those supplies. In the more populous sections of the country the quality of water is dependent to a large degree upon the amount and character of the pollution which is allowed to discharge into the streams. Therefore it has been found desirable to study different State laws regulating and controlling this matter and to determine the scope of the work to a large degree according to them.

Mr. Goodell has presented the subject of antipollution laws in a manner which will be of assistance to public officials, water companies, manufacturers, farmers, and legislators, rather than to members of the bench and bar. The broad legal principles under which antipollution statutes become operative are explained, and important court decisions are quoted to show authority for various deductions. The statutes enacted in the different States are classified according to the general scope, and an opportunity is thereby afforded to compare their effectiveness and desirability. In short, the paper provides specific information necessary to a popular knowledge of the conditions in each State with respect to one feature of the conservation of natural water resources. Its distribution should be of material assistance in bringing about a general apprehension of correct principles upon the subject.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

A REVIEW OF THE LAWS FORBIDDING POLLUTION OF INLAND WATERS IN THE UNITED STATES.

By Edwin B. Goodell.

This subject naturally divides into two parts: (1) A summary of the common law upon the subject of water pollution—i. e., the law as pronounced and determined by the courts independently of legislative action, and (2) a summary or abstract of the statutes enacted by the various legislatures for the correction of the evil.

WATER POLLUTION UNDER THE COMMON LAW.

The full treatment of this branch of the subject involves the examination of the very numerous decisions which have been rendered by the courts in England and the United States in the determination of litigation arising from alleged violations of the right to have inland waters preserved in their natural state. It necessarily follows that a full treatment of this branch of the subject would be beyond the scope of this paper. It is not the purpose of the present publication to furnish a complete work upon water pollution for the use of members of the bench and bar, but rather to put into the hands of public officials and others who may be interested in the subject a guide for their action and references to the sources from which a more exhaustive knowledge of the subject may be obtained if required.

No attempt, accordingly, will be here made to present a detailed statement of the entire law against water pollution as it exists independently of statutes, but this branch of the subject will be confined to a statement of the general principles which are to be deduced from the decisions, with references to some of the leading cases.

PRINCIPLES AND DECISIONS.

CLASSIFICATION.

These principles and decisions have been classified and are presented in the following groups:

A. The rights of riparian owners to pure water as against one another.

B. The rights of the public (as distinguished from individual owners) to have inland waters kept free from pollution by riparian owners or others.

C. The conditions under which, and the extent to which, public municipalities may use inland waters in disposing of sewage matter from public sewers.

A. RIGHTS OF RIPARIAN OWNERS TO PURE WATER AS AGAINST ONE ANOTHER.

In contemplation of law the water flowing over the land is part of the realty and belongs to the owner of the soil. But the latter's ownership thereof is a qualified one. He may use it in certain ways as it passes, may take from it for his own use to a certain extent, and may thus, incidentally, somewhat diminish its volume and slightly alter its character. But its nature is to pass on to the owners of the adjoining soil, and the next owner has precisely the same rights therein as every other owner. It follows, therefore, that as no riparian owner of a stream may appropriate all the water which comes to him, neither may he so corrupt or pollute it as to injure the other owners by diminishing the value of their property in the natural stream. This prohibition is independent of any statute; it is a part of the law of the land, except in certain of the arid and mining States of the West; its application in these is discussed on pages 21–23.

The conflict of rights between the several owners has given rise to litigation in many hundreds of instances, and it is impossible to give a rule, limiting the owner's right to use the water of a stream as it passes, more exact than this: Every owner may make such use of the water for farming and domestic purposes as is reasonable, and in the States in which the doctrine of prior appropriation obtains may use the water which he has acquired by appropriation, and the lower owners must accept the diminution and perturbation of the water which necessarily follows from this reasonable use.

If the use for farming or domestic purposes is challenged by another owner, the question of its reasonableness, in that case, is to be determined by court or jury as a question of fact.

If the water is used for any other than farming or domestic purposes, it must be such a use as will not change the character of the water from its natural state or make it less useful to other owners.

If the riparian owner cast sewage, filth, or waste material therein, he does it at his peril.

Independent of statutory provisions there is a remedy for these wrongs in the following ways:

By private suit against the wrongdoer for damages.

By injunction when the wrong is a continuing one.

By indictment when the injury affects the rights of the public.

Where the acts causing the pollution are done in one jurisdiction and the injuries suffered are in another, the injured party has his remedy in a civil action to the same extent as if the injurious act and the resulting injury were in the same jurisdiction.

These general principles will be found to be fully sustained by the cases. The following are given, not as an exhaustive list, but to enable the reader to find authorities if his needs require:

Alabama:

Drake *v.* Iron Co., 14 So. Rep., 749; 102 Ala., 501; 24 L. R. A., 64; 48 Am. St. Rep., 77.

Tenn. Coal Co. *v.* Hamilton, 14 So. Rep., 167.

Lewis *v.* Stein, 16 Ala., 214.

Arkansas:

State *v.* Chapin, 17 Ark., 561.

California:

Potter *v.* Froment et al., 47 Cal., 165.

People *v.* Elk River Mill and Lumber Co., 107 Cal., 214; S. C. 40 Pac. Rep., 486.

Mining Co. *v.* Mining Co., 48 Pac. Rep., 828.

People *v.* Gold Run Ditch Co., 66 Cal., 138; 56 Am. Rep., 80; 4 Pac. Rep., 1152.[a]

Colorado:

City of Durango *v.* Chapman, 60 Pac. Rep., 635.

Connecticut:

Morgan *v.* Danbury, 67 Conn., 484.

Nolan *v.* New Britain, 69 Conn., 668.

Georgia:

Satterfield *v.* Rowan, 83 Ga., 187; S. C. 9 S. E. Rep., 677.

Indiana:

Muncie Pulp Co. *v.* Martin, 55 N. E. Rep., 796.

State *v.* Herring (Ind., 1897), 48 N. E. Rep., 598.

State *v.* Wabash Paper Co., 48 N. E. Rep., 653.

Weston Paper Co. *v.* Pope, 155 Ind., 394.

Indianapolis Water Co. *v.* Am. Straw Board Co., 57 Fed. Rep., 1000.

Iowa:

Ferguson *v.* Mfg. Co., 77 Ia., 576; S. C. 42 N. W. Rep., 448.

Kinnaird *v.* Oil Co. (Ky.), 12 S. W. Rep., 937.

Maine:

Gerrish *v.* Brown, 51 Me., 256, 81 Am. Dec., 569.

Maryland:

Baltimore *v.* Warren Mfg. Co., 59 Md., 96.

Price *v.* Lawson, 74 Md., 499.

Massachusetts:

Ball *v.* Nye, 99 Mass., 582.

Martin *v.* Gleason, 139 Mass., 183.

Merrifield *v.* Lombard, 13 Allen, 16.

Woodward *v.* Worcester, 121 Mass., 245.

Dwight Printing Co. *v.* Boston, 122 Mass., 583.

McGenness *v.* Adriatic Mills, 116 Mass., 177.

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[a] This case was one brought in behalf of the people to restrain a public nuisance, caused by discharging the refuse from mining operations into an unnavigable stream. The injunction was granted and it was held that the right to pollute the stream in this manner could not be gained by prescription.

linnesota:
Roller Mills *v.* Wright, 30 Minn., 254.
lississippi:
Mississippi Mills *v.* Smith, 69 Miss., 299; S. C. 11 So. Rep., 26.
lissouri:
Smith *v.* Conathy, 11 Mo., 517.
ew Hampshire:
Hayes *v.* Waldron, 44 N. H., 580.
ew Jersey:
Holsman *v.* Boiling Springs Co., 1 McCart., 335.
Acquackanonk Water Co. *v.* Watson, 2 Stew. Eq., 366.
Beach *v.* Sterling Iron and Zinc Co., 9 Dick., 65.
Same case affirmed on appeal, 10 Dick, 824.
(See the opinion of Pitney, V. C., in the last-cited case, given in full on pp. 11–20.)
O'Riley *v.* McChesney, 3 Lans., 278.
Covert *v.* Cranford, 141 N. Y., 521.
Townsend *v.* Bell, 24 N. Y. S. (70 Hun, 557), 193.
Smith *v.* Cranford, 32 N. Y. S., 375.
hio:
The Columbus, etc., Co. *v.* Tucker, 48 Ohio St., 41; S. C. 26 N. E. Rep., 630.
Thayer *v.* Brooks, 17 Ohio, 489.
ennsylvania:
Elder *v.* Lykens Valley Coal Co., 157 Pa. St., 490.
Hindson *v.* Markle, 171 Pa. St., 138.
Stevenson *v.* Ebervale Coal Co., 201 Pa. St., 112.
hode Island:
Stillman *v.* Mfg. Co., 3 W. & M. (R. I.), 546.
Richmond Mfg. Co. *v.* Atlantic De Laine Co., 10 R. I., 106.
South Carolina:
Threatt *v.* Mining Co. (S. C., 1897), 26 S. E. Rep., 970.
Vermont:
Snow *v.* Parsons, 28 Vt., 459.
Canfield *v.* Andrew, 54 Vt., 1.
Wisconsin:
Middlestadt *v.* Starch Co. (Wis.), 66 N. W. Rep., 713.
Hazeltine *v.* Case, 46 Wis., 391.
Greene *v.* Nunnemacher, 36 Wis., 50.
Wyoming:
Howell *v.* Johnson, 89 Fed. Rep., 556.[a]
English:
Mason *v.* Hill, 5 B. & Ad., 1.
Embry *v.* Owen, 6 Exch., 353.
Wood *v.* Waud, 3 Exch., 748.
Bealey *v.* Shaw, 6 East, 208.

CASE IN EXCEPTION.

A single case in Pennsylvania seems to create an exception to the operation of the principles above stated, viz, Sanderson *v.* Pennsylvania Coal Company, 113 Pa. St., 126.

[a] In this case the injury arose from an act done in Montana, but the injurious result occurred in the State of Wyoming.

This was a case brought by a riparian owner who had established a home on the banks of a stream, after ascertaining, by a careful investigation, that its waters were uncontaminated by any influx of deleterious matter, and who used the waters of the stream for domestic purposes. Subsequently a coal mine was opened higher up the stream, and the mining company, in the course of its mining operations, pumped the water from the mine to the surface, where it ran into this stream and rendered the water unfit for domestic use. The case was bitterly contested, and came before the court several times. (See 86 Pa. St., 401; 94 Pa. St., 303, and 102 Pa. St., 370.)

In the final decision the court refused damages to the riparian owner. The reasoning of the court indicates that this result was due to its unwillingness to impose upon the immense coal-mining interests of the State the burden of paying for the damage to property in the water of streams caused by their operations; but the reason given for the decision, in the court's attempt to harmonize it with the principles firmly established by precedent in Pennsylvania, was that the water which the defendant conducted into the stream was contaminated only by the coal, which was a natural product, and hence was said to be conducted into the stream in its "natural state." This reasoning is specious, since the presence of coal in the brook was due wholly to the operations of the defendant company, the stream in its natural state showing no trace of coal, and the doctrine thus established for Pennsylvania has not found favor in any other jurisdiction.

But in subsequent decisions the courts of Pennsylvania have been careful not to extend the force of Sanderson *v.* Pennsylvania Coal Company beyond the single act of turning the natural drainage from a mine into a stream. (See Elder *v.* Lykens Valley Coal Co., 157 Pa. St., 490; Hindson *v.* Markle, 171 Pa. St., 138, and Stevenson *v.* Ebervale Coal Co., 201 Pa. St., 112.)

OPINION OF VICE-CHANCELLOR PITNEY, OF NEW JERSEY.

The whole subject was thoroughly treated in Beach *v.* Sterling Iron and Zinc Company (9 Dick. (N. J.), 65).

This was an action for an injunction, brought by the manufacturers of a white tissue paper against a mining company, the water from whose mines was pumped into the stream above the paper works and befouled the water, making it unfit for the purposes of the complainant. The opinion gives a careful and most lucid and interesting review of the course of decisions sustaining and enforcing the rights of riparian owners upon streams above tide water to have the water in the stream maintained in its natural condition. The decision of the court in this case was affirmed by the court of errors and appeals

(10 Dick., 824) upon the opinion of the court below, which is given here in full:

The material facts of the case are undisputed. The only dispute is as to the degree of discoloration caused by the defendant's operations and the length of time over which such discoloration extended.

The facts clearly established are as follows:

The Wallkill River rises in the southern part of Sussex County and flows upon a course nearly north, passing through the villages of Franklin and Hamburg. At the latter place is situated an artificial pond, called the Furnace Pond, caused by an old dam, upon which, for several years, has been a paper mill driven by the waters of the river from that pond. The complainant, Beach, purchased this water power and lands connected with it in the summer of 1891, for the purpose of erecting a plant for the manufacture of what is known as white tissue paper. Associated with him were two gentlemen by the name of Sparks, who had previously been engaged in the business of waxing white tissue paper according to a process which they controlled, and the project was to both manufacture and wax, for market, white tissue paper. For that purpose the corporation was formed, of which Mr. Beach and the Messrs. Sparks were stockholders, and the latter were the active managers. A large amount of money was spent in erecting a plant between the date of the purchase and the 1st of February, 1892, when they commenced the manufacture of white tissue paper and carried it on with success for about a year.

The manufacture of such paper requires a perfectly clear, pure water, and before purchasing the Hamburg water power the complainants inspected the stream and inquired as to its character for clearness, and satisfied themselves that they would be able to use it for making white tissue paper without incurring the expense of filtration, and their experience for a year proved that their expectations were just.

In the month of February, 1893, complaints began to come in from the purchasers of their paper that it was deteriorating in the matter of whiteness, and they investigated the cause. The pond was frozen over, but they knew by reputation that mining operations were being carried on at Greenspot by the defendant, and they went there March 1 and found a stream of highly colored water flowing from the defendant's mine shaft into the river, traced its effect in discoloration to their pond, and by subsequent observations by themselves and others in the neighborhood traced its effect not only in and through the Furnace Pond, but for miles down the river to the north of Hamburg. In fact, several respectable and credible witnesses, called by the complainants, testified to the discoloration of the water in the Furnace Pond and beyond, and the complainants were stopped by the court from producing further evidence on that subject in the opening of their case. Several witnesses called by the defendant, among them its superintendent, corroborated this evidence, and there is no attempt to meet it.

The color was a peculiar reddish-yellow tint, which was in marked contrast with the discoloration due to the ordinary road and field wash after a heavy storm or spring thaw.

This peculiar discoloration continued throughout the month of March and, with some intermissions and variations in degree of discoloration, through the month of April. Complainants early in March were obliged to stop the making of white tissue paper. Negotiations between the parties for some arrangement of the matter failing, the bill was filed on the 21st of April, 1893.

The immediate origin of the discoloration was as follows: The defendant corporation was organized by two gentlemen by the name of Heckscher and two by

the name of Wetherill for the purpose of reaching and working a bed of franklinite ore which had been located by boring exploration at a depth of about a thousand feet below the surface near this point called Greenspot. It was the continuation of a seam of ore for many years worked to the southwest of Greenspot by two companies, one of which—viz, the Lehigh Zinc and Iron Company—was owned and controlled by the Heckschers and Wetherills. In the spring or early summer of 1891 the defendant commenced to sink a perpendicular shaft, known as the "Parker shaft," 10 by 20 feet in diameter, and after passing through a small amount of superincumbent earth struck solid limestone rock. It continued the working without cessation until August 11, 1892, when, having attained a depth of 560 feet (many feet lower than the bed of the Wallkill), the workmen struck a water-bearing fissure or rent in the rock, which instantly flooded the mine and drove them out. Previous to that time they had encountered small seams or fissures from time to time, producing a little water and sometimes a little mud, which they pumped up, of course, carried through a trough or trunk several hundred feet westerly toward the Wallkill till it reached a small spring run, where it was discharged, and from thence it ran into the Wallkill. The amount of water up to August was small, and its discoloration was slight, so that it was not felt or observed by complainants. The influx in August, 1892, was discolored by a fine clay, amounting almost to a pigment, having a high reddish-yellow tint and intermixed with a small quantity of very fine sand. This water rose to within 40 feet of the surface, and resisted all attempts to lower it by the pumps then in use and until very large and heavy pumps were introduced. This was done in September. After the shaft filled with water there was no further movement; it became perfectly quiet, and the clay and sand began to settle, so that the water in the upper reach of the shaft became comparatively clear. The first water that was discharged after heavy pumping commenced came from near the top and was but slightly discolored, such discoloration being due to the disturbance of the clay and sand which had settled on the timbering of the shaft. The quantity of water struck in the fissure was so great that with these powerful pumps very slow advance was made, the pumps being lowered from time to time, and the greater the depth attained the less rapid the advance and the greater the discoloration.

On about the 1st of January, 1893, the water was reduced to a depth of 420 feet from the surface, and a delay there occurred of about three weeks, caused by the necessity of establishing a pumping station at that point. When the rapid pumping commenced again, at or near the 1st of February, the discharge was much discolored, and continued growing worse and worse until the bottom was reached, and there, without detailing the circumstances, the greatest discoloration was reached, and continued during the month of March. The discoloring clay is so very fine in its texture that a very slight movement of particles of water with which it comes in contact will thoroughly mix it, and it will only subside in perfectly still water. This accounts for the fact that it did not fully subside in passing through complainants' pond, which is quite narrow, so that it is probable that the volume of the water of the Wallkill causes continued motion throughout its length.

After the shaft had been entirely pumped out and the volume of water stored in the fissure had been entirely exhausted and the flow reduced to the natural supply of the fissure, and the various water channels which had been created throughout it by the sudden drawing off of the water had arrived at what the experts call an "angle of repose," so that no further scouring resulted from the flow of the ordinary quantity of water, there was no discoloration and the water ran clear. This condition was, as claimed by the defendant, reached some time in the summer of 1893, and the case shows that from about the middle of April

or the 1st of May till about the middle of July the discolorations were temporary and increasingly infrequent, and usually the result of clearing out the different settling basins, called "sinks," which had been established in the rock at different points in the shaft. Since that time the shaft has been sunk over 200 feet without finding any more water or fissures.

The proof is clear that the result of the contribution of this discolored water to the waters of the river was to render the mixture when it reached complainants' mill unfit, without filtration, for use in making white paper.

An ingenious experiment was made by an expert, as follows: He ascertained, by a rough measurement, that the flow of the river was about forty times that of the output from the mine, and he took a jar of perfectly clear water and mixed with it one-fortieth of its quantity of the dirty water that came from the mine, and exhibited the sample to show to what a slight extent it was discolored.

The dirty water which he used had been confined in a jar for several months, with the result that the fine particles of clay had partially coagulated and gathered into little flakes, and when shaken up did not produce the same degree of discoloration as exhibited when freshly taken from the running stream. But even that experiment showed that the result of so slight a mixture made the whole mass palpably roily. In point of fact, as shown by the evidence of the expert paper makers, a very small admixture of mud or clay will render the water improper, without filtration, for making white tissue paper; and the effect of that evidence is that the river in its ordinary clear state is no clearer than is necessary for that purpose. A very small admixture of coloring or dirty matter renders it unfit for use.

Several matters are urged in defense to this case. First, but faintly, that the doctrine finally established by a bare majority of a divided court in Pennsylvania, in Sanderson *v.* The Coal Company (86 Pa. St., 401; 94 Pa. St., 303; 102 Pa. St., 370, and 113 Pa. St., 126), should be adopted here. The history of that case, in its various phases, is given by a writer in the American Law Register (n. s.), vol. 1, p. 1 (1894). It was an action, as here, by a riparian proprietor against a mining company for polluting a natural stream with water pumped from its mine. After three decisions by the supreme court of Pennsylvania in favor of the plaintiff's right, that court finally held the contrary and affirmed the right of the coal company to discharge its acid mine water into the creek, without regard to its effect upon lands below, upon the broad ground that the necessities of the mining interests of the Commonwealth required it. This result was attributed by the author of the article in the American Law Register (pp. 5, 18), in part, to a lack of care on the part of the learned judge who prepared the first prevailing opinion (86 Pa. St., 406). The doctrine of that case is shown by that writer to be inharmonious with a long line of previous decisions in Pennsylvania, and has not been, so far as I can learn, followed in any other State—certainly not in this State. It was repudiated in Ohio, whose mining interests are quite large, in the recent and well-considered case of The Columbus, etc., Co. *v.* Tucker (48 Ohio St., 41). I refer particularly to the lucid expressions of the learned judge found on pages 58 and 62.

It was not suggested on the argument that the doctrine ever had the least foothold in this State. No case of a stream fouled by mining operations has indeed ever, so far as I know, been presented to our courts, but the right of a riparian proprietor to have the waters of the stream come to him unchanged in quality, as well as undiminished in quantity, has been determined in the clearest and most positive manner. In fact, the doctrine stated so tersely by Chancellor Kent in Gardner *v.* Newburgh (2 Johns. Ch. 162, at p. 166)—"A right to a stream of water is as sacred as a right to the soil over which it flows. It

is a part of the freehold"—has always been adhered to by our courts. I need refer only to Holsman *v.* Boiling Spring Co. (1 McCart., 335), and Acquackanonk Water Co. *v.* Watson (2 Stew. Eq., 366). In the last case the right was stated by the learned master in an extremely clear and comprehensive manner, and the decree advised by him was unanimously affirmed on appeal, for the reasons by him given.

The facts of that case are, in a manner, analogous to those here under consideration. Watson owned and operated a bleachery which required for use clear and pure water, which he obtained from a small stream running through his land. The water company, desiring to supply the city of Passaic with potable water, proposed to take this small stream above the bleachery and substitute for it an equal or greater quantity of Passaic River water, drawn from the Dundee Canal and used to drive its pumps. This the court restrained, on the ground that the substituted water was not of equal purity with that abstracted.

There is a line of cases of pollution by mine water in England which sustains the general doctrine. Hodgkinson *v.* Ennor (4 Best and S., 229) was the case, as here, of a paper maker against a miner who had permitted dirty washings of lead ores to run through rents, called "swallets," in limestone rock into a subterraneous stream, rendering the water, which in its course came to plaintiff's paper mill, unfit for use in the manufacture of paper, and the action was sustained by Chief Justice Cockburn and Justices Blackburn and Mellor.

Magor *v.* Chadwick (11 Ad. and E., 571) was a suit by a brewer against a miner.

Pennington *v.* The Brinsop Coal Co. (L. R., 5 Ch. Div. 769) (1877) was a suit by a manufacturer against a coal miner, where the only allegation of injury was that the acid contributed to the water from the mine rendered it less fit for use in the engine boilers driving the machinery of the plaintiff's mill. An injunction was allowed. Defendant relied, without success, upon the ground taken in Sanderson *v.* The Coal Co., supra, that the acid could not be removed from the water; that there was no means of remedying the evil, and an injunction would absolutely stop its work. The learned judge (Fry) refused even to exercise the right given by the English statute to give damages instead of an injunction, relying on Clowes *v.* Staffordshire Waterworks (L. R., 8 Ch. App., 125) (1873), and he declared that he would have granted the injunction, although the present damage was only nominal, because of the injury to the riparian rights of the plaintiff, and such is the doctrine of the case relied on, which was a suit by a silk dyeing and washing establishment against a waterworks company for rendering the water coming to their works less clear and pure.

The English cases dealing with pollution by mine water culminated in the case of Young *v.* Bankier (L. R., App. Cas., 691) (1893), in the House of Lords, on appeal from Scotland. The case was argued, elaborately, of course, before six law lords, whose unanimous judgments were delivered after consideration. The riparian proprietor (Bankier), the plaintiff there, was a distiller, and used the water of the stream in his distilling process, presumably for making mash, for which it was peculiarly fit by reason of its softness. The added mine water did not render it unfit for ordinary purposes—there called primary purposes—but by reason of its hardness rendered it less fit for distilling purposes. Sanderson *v.* The Coal Co. was cited, but the court repudiated its doctrine and was unanimous in judgment in favor of the respondent, who was the plaintiff and had judgment below. Lord Macnaghten, at page 699, says: "Then the appellant urged (precisely as does the defendant here) that working coal was the natural and proper use of their mineral property. They said they could not continue to work unless they were permitted to discharge the water which

accumulates in their mine, and they added that this water course is the natural and proper channel to carry off the [illegible]lus water of the district. All that may be very true, but in this country, at any rate, it is not permissible in such a case for a man to use his own property so as to injure the property of his neighbor."

There are numerous English cases upon the general right of a riparian proprietor to have the waters of his stream come to him in its natural condition, of which I cite Crossley *v.* Lightowler (L. R., 3 Eq. Cas., 279; 2 Chan. App., 478) (1867); Attorney-General *v.* Lunatic Asylum (L. R., 4 Ch. App., 145) (1868). Numerous other cases will be found cited in Gould, Waters, section 219, and in Higg. Pol. Waterc., 132 et seq.

The argument was advanced by the defendant that the use of the defendant's property for mining purposes is what was termed, unfortunately, I think, by Lord Cairns, in Fletcher *v.* Rylands (L. R., 3 H. L., 330, at pp. 338, 339) (1868), a natural user, and similar in that respect to plowing a field, and that if it be unlawful for defendant here to cast into the stream the muddy waters from its mine it is also unlawful for the farmer to plow his land and allow the muddy water which runs from it after a heavy rain to reach the river. But the very statement of the two cases shows the absence of analogy between them. In the first place, the water from the plowed field comes thereon by natural causes beyond the farmer's control and runs by gravity to the stream, while in the case of the mine the water is, as here, found and raised by artificial means from a level far below that of the river and would never reach it but for the act of the miner, and in the second place, by the common law of the land every owner may cultivate his land without regard to its effects upon his neighbor, while such is not the law as to mining. The supreme court of Ohio, in Columbus Company *v.* Taylor (48 Ohio, 41, at p. 58), repudiates the notion that mining was a natural use of the land in the sense that farming is.

The ground of a reasonable natural user seems to be at the bottom of what was said in Merrifield *v.* Worcester (110 Mass., 216) upon this topic. So far as the expressions there used favor the notion that a city or town may collect and discharge sewage matter into a fresh-water stream to the injury of a riparian owner without liability to action they are contrary to the law as held in England for centuries. See Higg. Pol. Waterc., 127 et seq., where several cases besides these above cited are collected.

Equally untenable is another position advanced by the defendant, viz. that the river was always more or less polluted by contributions from other mines and from the washing of plowed fields, public roads, and railroad embankments. Such insistments have been frequently made and always overruled. The question in such cases seems to be whether the stream has already become so far polluted by contributors who have acquired a right so to do by adverse use or otherwise as that the pollution presently opposed will not sensibly alter its condition. And even in such a case the courts have held that the party has the right to deal with each contributor in detail and to buy off such contributors as have acquired a right, and is not obliged to submit to fresh contributors. I cite the following authorities: Ross *v.* Butler (4 C. E. Gr., 294, at p. 306); Attorney-General *v.* Steward (5 C. E. Gr., 415, at p. 419), where the learned chancellor says: "The defendants have no right to pollute or corrupt the waters of the creek, or if they are already partially polluted to render them more so;" to Cleveland *v.* The Gas Co. (5 C. E. Gr., 201, at p. 208); and to Meigs *v.* Lister (8 C. E. Gr., 199, at p. 205), where the learned chancellor says: "The position taken by counsel that the complainants were entitled to no relief from this nuisance because the locality was surrounded by other nuisances and dedicated

to such purposes has no foundation in law or in fact. If there were several nuisances of the like nature surrounding them, they must seek relief from each separately. They can not be joined in one suit nor need the suits proceed pari passu."

In Crossley v. Lightowler (L. R., 2 Ch. App., 478, p. 481, 1867) Lord Chelmsford says: "But the defendants contend that the plaintiffs have no right to complain of any pollution of the Hebble occasioned by them, because there are many other manufacturers who pour polluting matter into the stream above the plaintiffs' works, so that they never could have the water in a fit state for use even if the defendants altogether ceased to foul it. The case of St. Helen's Smelting Co. v. Tipping (11 H. L. Ch., 642; 11 Jur. N. S., 785), is, however, an answer to this defense. Where there are many existing nuisances, either to the air or to water, it may be very difficult to trace to its source the injury occasioned by any one of them; but if the defendants add to the former foul state of the water and yet are not to be responsible on account of its previous condition, this consequence would follow that if the plaintiffs were to make terms with the other polluters of the stream so as to have water free from impurities produced by their works, the defendants might say, 'We began to foul the stream at a time when, as against you, it was lawful for us to do so, inasmuch as it was unfit for your use, and you can not now, by getting rid of the existing pollutions from other sources, prevent our continuing to do what, at the time when we began, you had no right to object to.'" (Attorney-General v. Lunatic Asylum, 4 Ch. App., 145, p. 150, report of the expert, and p. 155.)

In Attorney-General v. Leeds (L. R., 5 Ch. App., 583, p. 595, 1870) the lord chancellor says: "I think the argument deduced from the foul state of the water before it gets to Leeds is not deserving of any weight for two reasons: First—and it is hardly disputed—the evil did become seriously aggravated when the new sewer was opened—that is to say, sixteen or seventeen years ago; and, secondly, the nuisance might terminate; and no one can say it was right that when one nuisance terminates there should be another brought into existence."

The sensible and material increase in the discoloration of the water, in this case resulting from the contribution of the defendant's mine, is clearly proved. The complainant was able to make white paper successfully and satisfactorily from February 1, 1892, for nearly a year, and until the serious discharge of discolored water from the defendant's shaft, in January, 1893; and they were also able to make such paper after the discolored water ceased to run, in June or July, 1893. During the intermediate period, while the discoloration of the water being discharged from the defendant's mine was the greatest, complainant could not make white paper satisfactorily.

In whatever point of view the complainant's case is considered it seems entirely clear and free from doubt. I can not think the least doubt is cast upon the law by the last decision in the Sanderson case, in Pennsylvania, and the facts of the case are substantially undisputed. The complainants' title and possession of the ripa, though put in issue by the answer, is established by the proofs and was finally admitted at the hearing. Their right to have the water come to them in its natural condition follows inevitably. (Holsman v. Boiling Spring Co., 1 McCart., 335, at p. 343, bottom, and cases there cited.) The learned chancellor there says: "Where the complainant seeks protection in the enjoyment of a natural water course upon his land, the right will ordinarily be regarded as clear. And the mere fact that the defendant denies the right by his answer or sets up title in himself by adverse user will not entitle him to an issue before the allowance of an injunction."

There can be no doubt that, upon the facts presented, it would be the duty of a judge to direct a verdict, and the rule adopted by the court of errors and appeals in Higgins *v.* The Water Co. (9 Stew. Eq., 538) applies. I refer to the language of the chief justice on page 544 et seq.

The jurisdiction of this court to adopt, on final hearing, the extreme remedy of an injunction in this class of cases, when the right is clear, is well established, not only by the case just cited, but by Acquackanonk Water Co. *v.* Watson, supra, which was decided by the court of errors and appeals, and by Holsman *v.* Boiling Spring Co., supra, decided by Chancellor Green, and by Shields *v.* Arndt (3 Gr. Ch., 234), and by Carlisle *v.* Cooper (6 C. E. Gr., 576).

It was suggested that in this case no injunction should be ordered, but that the complainants should be left to their action at law for damages. I am unable to adopt that view. It must now be considered as settled law in this State that the maintenance of a nuisance of the kind here in question is, in effect, a taking of property. Pennsylvania Railroad Co. *v.* Angel (14 Stew. Eq., 316, p. 329), where Judge Dixon, speaking for the court of errors and appeals, says: "This principle rests upon the express terms of the Constitution. In declaring that private property shall not be taken without recompense, that instrument secures to owners not only the possession of property, but also those rights which render possession valuable. Whether you flood the farmer's fields so that they can not be cultivated, or pollute the bleacher's stream so that his fabrics are stained, or fill one's dwelling with smells and noise so that it can not be occupied in comfort, you equally take away the owner's property. In neither instance has the owner any less of material things than he had before, but in each case the utility of his property has been impaired by a direct invasion of the bounds of his private dominion. This is the taking of his property in a constitutional sense. Of course, mere statutory authority will not avail for such an interference with private property. This doctrine has been frequently enforced in our courts," and he proceeds to cite previous authorities in the same court. If this be so, then the legislature has no power to authorize the maintenance of a nuisance for the promotion of private objects, even upon terms of making compensation; for no authority is necessary for the position that the legislature is powerless to enact a law declaring that defendant may have complainants' mill and water power upon terms of paying them what a court may ascertain it is worth. And I am unable to distinguish such action and that of leaving complainants to the remedy of repeated actions at law to recover damages as often as they are suffered. In this respect our system of laws varies from that of England, where Parliament is omnipotent and is not confined to the mere making of laws—the true function of a legislature—but may take private property for private purposes, with or without making compensation, the only restraint upon its power being its own innate sense of justice. Hence the English courts are authorized, in cases of certain nuisances, to give damages once for all instead of an injunction.

The result of my consideration of the subject is that there is no principle which will sustain a court of equity in refusing an injunction against the maintenance of an established continuing nuisance and leaving the injured party to his remedy at law. To do so is, in effect, to permit a party to take his neighbor's land for his own use upon terms of making such compensation as a jury shall assess. This is inadmissible.

The object and office of a verdict and judgment at law is to establish the right and give compensation for past injuries. The right being once made clear, whether by judgment at law or upon incontrovertible rules of law and well-established facts, the remedy in equity by injunction to prevent future injury is a matter of right, and the relief can not be refused.

The ground, however, mainly relied upon by defendant is that the proofs show that the nuisance has entirely abated and that there is no danger of its recurrence, and hence an injunction is unnecessary and improper.

At about the time the injunction was issued—July 17, 1893—defendant purchased a small tract of land skirting the railroad, between the shaft and the river, and established on it a settling basin, into which the mine water was turned and given opportunity for subsidence before reaching the river. The result was that it was substantially clear, and no further injury has been since felt at the paper mill. It is also in proof that from that time up to July, 1894, the water was usually clear when it came from the mine. At the sessions of December 27 and December 28, 1893, Professor Nason, a competent geologist and mining expert, testified that, in his opinion, no further clay and water-bearing seams or rents would be met in the course of defendant's mining operations, and that the rent which had given so much trouble had, by natural causes, become harmless. It was not suggested that all or any large proportion of the discolored clay deposit had been removed, but the theory was that the descending water had worn channels in the clay, resulting in little rivulets centering at the section by the shaft, and that the scouring power of the water—that is, its power to bring down clay—had ceased by reason of the clay banks and beds of the little rivulets having arrived at an "angle of repose." The stability of this state of affairs depends, of course, upon the uniformity of the flow of water, both as to quantity and source of inflow, and Professor Nason, on cross-examination, admitted some uncertainty in this respect. After his examination and the close of the evidence on both sides, and before the argument, viz, about July 16, 1894, an unexpected influx of muddy water occurred, due to an overflow from a flume carrying water from the neighboring mine of the Lehigh Zinc and Iron Company, which found its way into the seam or rent at a point where it came to the surface, about 1,800 feet from the Parker (defendant's) shaft. This opening was a surface fissure or swallet in the rock—quite common where limestone rocks come to the surface. In this case, as I understand Professor Nason, he did not suppose or infer, from the trend of the fissure, that it reached the surface in that neighborhood, but such was the fact. It was promptly stopped by defendant and filled up, so as to prevent any more water getting in at that point.

Now, it seems to me that this occurrence shows the impossibility of affirming that there will be no further incursions of muddy water. It is true that with the continued use of the settling ground no injury will probably result to complainants from such an irruption. I say "probably," because, in case of a sudden irruption of discolored water, the quantity might be so great as to overwork the present settling basin. But without a decree and injunction the defendant will be at liberty to discontinue its use and permit any muddy water that may appear to flow into the Furnace Pond as of old.

At the time the complainants filed their bill the injury was serious and continuous. The defendant positively declined to stop it, but claimed the right to continue it. To complainants' bill was interposed a general denial, and setting up a right to persist in the injury as long as its necessities required. On all these issues the defendant is beaten. The complainants have established their case, and it would seem to be a most lame and impotent conclusion to refuse to give them the very relief prayed for, viz, a perpetual injunction. I am unable to imagine any other decree in their favor which would adequately meet the case and give them the just fruits of their suit; and, surely, if there is no danger of further discoloration the injunction will do the defendant no harm, but will be of value as a muniment of title to the complainants' property. The language of Lord Justice Turner, in Goldsmid *v.* Tunbridge Wells Commissioners (L. R., 1 Ch., App., 349, p. 355), applies: "In this particular case I think that regard

must be had not merely to the comfort or convenience of the occupier of the estate, which may only be interfered with temporarily and in a partial degree, but that regard must also be had to the effect of the nuisance upon the value of the estate and upon the prospect of dealing with it to advantage; and I can not but think that the value of this estate, and the prospect of advantageously dealing with it, is and will be affected by the continuance of this nuisance."

But the defendant further urges that the complainants have manifested a disposition to make an unreasonably harsh and oppressive use of their rights in the premises, and have thereby weakened their standing in equity and disentitled them to the extreme decree asked for.

In the month of March, 1893, while the outflow from the mine was at its worst, negotiations took place between the parties for some sort of settlement, and a filter was mentioned. The complainants offered to be satisfied if defendant would furnish them with a filter of proper size, which they said, and about which there is no dispute, would cost $5,000. The defendant offered to pay one-half of the expense of the filter, the same to be in full compensation for all damages up to the time it was furnished, which offer the complainants refused to accept. I can see nothing harsh or oppressive in that refusal.

Next, and after bill filed, as I now recollect, defendant made an arrangement with the tenant of a gristmill, located upon a little stream which empties into the Furnace Pond, for a right to divert water from the mill and carry it by a flume several hundred feet down to the complainants' works and furnish them with clear water from that stream. Complainants employed an expert to examine the stream and see whether it would supply sufficient water for their paper engines, with the result that they were informed and believed that it was not sufficient, and declined to accept it as a substitute for the river water. The defendant, nevertheless, in the face of complainants' refusal, built the flume—a mere wooden trough, set upon benches and trestles—along the surface of the ground down to the mill yard of the complainants. The complainants refused to allow it to be put across their mill yard, because it would prevent them from having access to their works and from free passage with carts and wagons from one part to the other, and said that anything of that kind must be put underground in iron pipes. But the radical difficulty with that movement on the part of the defendant was that the right to the use of the water was merely obtained temporarily from a mere tenant of the mill property, and did not give the complainants any permanent right to the flow of the stream, even if it had been large enough for their purposes. I can see nothing harsh or oppressive in complainants' action in refusing this offer of substitution. They not only had the strict right in law to refuse to accept them, but their conduct in so doing, in my judgment, was not inequitable.

I shall advise a decree establishing the complainants' right to the flow of the stream in its natural condition and an injunction with costs.

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Where an injurious act in one State is so far-reaching in its injurious consequences as to threaten the rights of property and the health of a large number of citizens in another State, the latter State may become a party complainant in the Supreme Court of the United States to enforce the legal remedies of its citizens for such injuries. (Missouri *v.* Illinois et al. (U. S. Supreme Court, October term, 1900), 180 U. S., 208.)

This was a case in which the State of Missouri sued to restrain the State of Illinois and the Sanitary District of Chicago from carrying the sewage of Chicago through an artificial channel to the Mississippi River. The right of the State of Missouri to protect its citizens by this action and to implead the State of Illinois as a party defendant and to have an injunction against the defendants in case the facts alleged in its bill should be established was upheld by a divided court in overruling a demurrer to the bill. The defendants have answered, but at the time of the present writing the final hearing has not been reached.

RIGHTS OF RIPARIAN OWNERS IN ARID AND MINING STATES.

In certain of the arid and mining States of the West the doctrine of riparian rights has been in whole or in part abrogated by what is known as the doctrine of prior appropriation. Where the latter doctrine prevails the rights of riparian owners as given above do not exist, and where the doctrine of prior appropriation has been adopted in part the rights of appropriators to some extent supersede the rights of riparian owners.

"Appropriation" is an actual use of the water for a beneficial purpose by a person having the right to make such use, i. e., by any person having lawful access to the water. The appropriator, by the fact of appropriation, acquires the right, as against riparian owners, to use the water in the state and condition and to the extent necessary for the purpose for which he has appropriated it. Subsequent appropriators also acquire rights, but such are subordinate to the rights of the prior appropriator.

The doctrine of prior appropriation has been adopted to the extent indicated in the States mentioned below:

Arizona:
- Clough *v.* Wing, 17 Pac. Rep., 453.

Colorado:
- "The right to divert unappropriated waters of any natural stream shall never be denied." Const., Art. XVI, sec. 6.
- Wheeler *v.* Northern Colorado I. Co., 10 Col., 582.
- 3 Am. St. Rep., 603; 17 Pac. Rep., 487.

Idaho:
- Constitution of 1889, Art. XV, sec. 3.
- Wilterding *v.* Green, 45 Pac. Rep., 134; 4 Idaho, 773.

Montana:
- Constitution, Art. III, sec. 15.
- Smith *v.* Denniff, 24 Mont., 20.
- 81 Am. St. Rep., 408; 60 Pac. Rep., 398; 50 L. R. A., 741.

Nevada:
- Reno Smelting, etc., Works *v.* Stevenson, 20 Nev., 269.

New Mexico:

Compiled Laws of New Mexico, sec. 23.

Albuquerque Land and Irr. Co. *v.* Gutierrez, 61 Pac. Rep., 357.

North Dakota:

Springville *v.* Fullmer, 7 Utah, 450.

Stowell *v.* Johnson, 7 Utah, 215.

Wyoming:

Farm Investment Co. *v.* Carpenter, 9 Wyo., 110; 50 L. R. A., 747; 61 Pac. Rep., 288.

In California the common law as to riparian rights seems to prevail, except as to rights acquired by appropriation upon public lands made before any riparian owner has acquired title to lands below. (Lux *v.* Haggin, 69 Cal., 254.)

In Oregon the right of appropriation is confined to such rights as were acquired before Washington became a State, under an act of Congress passed in 1866. (Simmons *v.* Winters, 21 Oreg., 35; 28 Am. St. Rep., 727; 27 Pac. Rep., 7.)

In Washington the right of appropriation seems to be recognized, at least as to the portion east of the Cascade Mountains in that State, but not as against settlers who have obtained riparian rights before the appropriation.

Isaacs *v.* Barber, 30 L. R. A., 665.

10 Wash., 124; 45 Am. St. Rep., 772.

38 Pac. Rep., 871.

Benton *v.* Johncox, 39 L. R. A., 107; 17 Wash., 277.

61 Am. St. Rep., 912; 49 Pac., 495.

In several of the arid or partly arid States not included in the above list the riparian owner holds subject to the right of those owning above him to a *reasonable* use of the water for irrigation purposes.

Rhodes *v.* Whitehead, 27 Tex., 309; 84 Am. Dec., 631.

Tolle *v.* Carreth, 31 Tex., 362; 98 Am. Dec., 540.

Fleming *v.* Davis, 37 Tex., 173.

Baker *v.* Brown, 55 Tex., 377.

Mud Creek Irr., etc., Co. *v.* Vivian, 74 Tex., 170; 11 S. W. Rep., 1078.

Barrett *v.* Metcalf, 12 Tex. Civ. App., 247; 33 S. W. Rep., 758.

So far as the doctrine of prior appropriation is recognized, the rights of riparian owners are pro tanto extinguished. In such States, therefore, the general statements already given require modification.

In States where the doctrine of prior appropriation is established it may be safely asserted:

1. That the riparian owners can not complain of pollution so far as such pollution necessarily results from the use for which the appropriator has appropriated the water.

2. That no person, except a prior appropriator, may pollute the stream so as to render the water less fit for use by one who has law-

fully appropriated it, and such prior appropriator can not so pollute the water by a subsequent appropriation to a new use.

Fairplay Hydraulic Mining Co. *v.* Weston, 29 Colo., 125.

3. No appropriator or other person may pollute waters to the extent of creating a public nuisance.

Woodruff *v.* North Bloomfield Gravel Mining Co., 8 Lawy., 628; 16 Fed. Rep., 25; 9 Lawy., 441; 18 Fed. Rep., 753.
People *v.* Gold Run Ditch, etc., Co., 66 Cal., 138; 56 Am. Rep., 80; 4 Pac. Rep., 1152.
Carson *v.* Hayes, 39 Oreg., 97; 65 Pac. Rep., 814.
Suffolk Gold Min. and Milling Co. *v.* San Miguel Consd. Mining and Milling Co., 9 Colo. App., 407; 48 Pac. Rep., 828.
Nixon *v.* Bear River and A. Water Co., 24 Cal., 367; 85 Am. Dec., 69.
Levaroni *v.* Miller, 34 Cal., 231; 91 Am. Dec., 692.
Yuba Lake, etc., Co. *v.* Yuba Co., Super. Ct., 66 Cal., 311; 5 Pac. Rep., 490.
McLaughlin *v.* Del Re, 71 Cal., 230; 16 Pac. Rep., 881.

B. RIGHTS OF THE PUBLIC (AS DISTINGUISHED FROM INDIVIDUAL OWNERS) TO HAVE INLAND WATERS KEPT FREE FROM POLLUTION BY RIPARIAN OWNERS OR OTHERS.

Whenever the pollution of a stream or other body of water injuriously affects the health or materially interferes with the peace and comfort of a large and indefinite number of people in the neighborhood, such pollution becomes what is known as a public nuisance. But, except under such circumstances, the public, as such, has no standing to prevent the pollution of waters. When, however, there is a public or quasi-public ownership of the banks of a stream, as in the case of a source of water supply owned by a municipality or owned by a company which supplies the inhabitants of a municipality with water, the public is interested in the enforcement of the rights of riparian proprietors, as stated under heading "A."

Where there is a public nuisance caused by the pollution of water, it is the duty of public authorities to cause its abatement, and their right to do so has been sustained in numerous cases. Where the public is injured in its capacity of riparian owner the remedy is either by injunction or by criminal proceedings, according to the nature of the wrong and the laws and practice of the jurisdiction in which the offense occurs.

The following are cases in which the pollution of water has been held to be a public nuisance:

Board of Health *v.* Casey, 3 N. Y. S., 399.
People *v.* Elk River Mill and Lumber Company, 107 Cal., 214.
State *v.* Taylor, 29 Ind., 517.
Greene *v.* Nunnemacher, 36 Wis., 50.

C. CONDITIONS UNDER WHICH, AND EXTENT TO WHICH, PUBLIC MUNICIPALITIES MAY USE INLAND WATERS IN DISPOSING OF SEWAGE FROM PUBLIC SEWERS.

This subject has but recently been receiving attention from the courts. It seems to have been the custom of municipalities to discharge their sewers freely into the larger streams, and until within the last few years but little, if any, objection to the practice has found its way into the courts. Latterly the increase of population, with the consequent increase of the amount of sewage matter so discharged, has brought about a condition of affairs that has produced opposition and in many cases litigation. The principles established by the decisions thus made necessary are briefly summarized as follows:

Municipalities, if riparian owners, have the same rights and are subject to the same restrictions in the use and treatment of the water flowing over their lands as private owners are—i. e., they may deposit sewage and other filth in such waters, provided always that by so doing they cause no injury to property below them. They may drain the surface water from their streets into water courses, with the impurities which it naturally carries, provided they do not thereby increase the flow of water into the stream so as to exceed the capacity of the channel to the injury of property below.

Brainerd *v.* Newton, 154 Mass., 255; 27 N. E., 995.
Cone *v.* Hartford, 28 Conn., 363.

Where municipalities are expressly authorized by statute to construct a system of sewerage, and to cause the sewage matter to be discharged into any particular waters, the statutory authority is to be exercised subject to the implied condition that such discharge will not constitute a nuisance. Legislative authority can go no further than to authorize municipalities to acquire the rights of lower owners by purchase or condemnation, because of the constitutional restriction against taking private property for public use without just compensation.

It will thus be seen that the increase of population under the present conditions and with the now prevalent methods of sewage disposal in cities is rapidly leading to a condition of affairs which will call for radical changes. Many cities will find themselves unable to dispose of their sewage matter by means of rivers without enormous expense, and probably not without additional legislation. As will be seen hereafter, the subject is already receiving serious attention from legislators.

CITATION OF CASES.

The following cases will be found to sustain the general principles above stated:

English:

Goldsmid *v.* Tunbridge Wells Imp. Com., L. R., 1 Chan. App., 349.
Holt *v.* Rochdale, L. R., 10 Eq. Cases, 354.
Attorney-General *v.* Leeds, L. R., 5 Chan. App., 583.
Attorney-General *v.* Richmond, L. R., 2 Eq. Cases, 306.
Attorney-General *v.* Hackney Local Board, L. R., 20 Eq. Cases, 626.
Attorney-General *v.* Cockermouth Local Board, L. R., 18 Eq. Cases, 172.
Attorney-General *v.* Luton Local Board, 2 Jurist, 180.
Attorney-General *v.* Halifax, 39 L. J. (N. S.), 129.
North Staffordshire R. R. Co. *v.* Tunstall Local Board, 39 L. J., Chan., 131.
Attorney-General *v.* Kingston on Thames, 34 L. J., 481.
Attorney-General *v.* Basingstoke, 45 L. J. (N. S.), 726.
Attorney-General *v.* Colney Hatch Lunatic Asylum, L. R., 4th Ch. Div., 146.
Attorney-General *v.* Birmingham, 4 Kay & Johns., 528.
Attorney-General *v.* Metropolitan Board of Works, 1 H. & M., 298.
Bidder *v.* Croyden Local Board, 6 L. T., 778.
Manchester, etc., Railway Co. *v.* Worksop Board of Health, 23 Beav., 198.
Oldaker *v.* Hunt, 6 De Gex, McN. & G., 376.

Alabama:

Birmingham *v.* Land, 374 So. Rep., 613.

California:

People *v.* City of San Luis Obispo, 116 Cal., 617.
Peterson *v.* City of Santa Rosa, 51 Pac. (Cal.), 557.

Connecticut:

Morgan *v.* Danbury, 67 Conn., 484.
Nolan *v.* New Britain, 69 Conn., 668.
(See extracts from opinions in the Conn. cases given below.)

Georgia:

Columbia Av. Savings Fund, etc., Co. *v.* Prison Commission of Georgia, 92. Fed. Rep., 801 (Cir. Ct. West Div. Ga., 1899).

Illinois:

Village of Dwight *v.* Hayes, 150 Ill., 273.
Robb *v.* Village of La Grange (1895), 158 Ill., 21.
Barrett *v.* Cemetery Assn., 159 Ill., 385.

Indiana:

Valparaiso *v.* Hagen, 153 Ind., 337; 48 L. R. A., 707; 74 Am. St. Rep., 305; 54 N. E., 1062.[a]

Iowa:

Randolf *v.* Town of Bloomfield, 77 Ia., 50.
Loughran *v.* City of Des Moines, 72 Ia., 382; S. C. 34 N. W. Rep., 172.

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[a] In this case it was held that where a municipality acts in conformity to the statute, skillfully and without negligence, it may discharge its sewage into a stream and the lower proprietors may not have an injunction, and are entitled to no compensation for the damages suffered by them.

This seems to settle the law in that State; but the reasoning is not convincing, and it is believed no other State has, so far, adopted that rule, which might, perhaps, be held violative of that clause of the Constitution of the United States which forbids the taking of private property for public use without compensation.

Kansas:

Topeka Water Supply Co. *v.* City of Potwin, 43 Kan., 404.

Massachusetts:

Brainard *v.* Newton (Mass. Sup.), 27 N. E. Rep., 995, and 154 Mass., 255.
Morse *v.* Worcester, 139 Mass., 389.
Boston Rolling Mills *v.* Cambridge, 117 Mass., 396.
Haskell *v.* New Bedford, 108 Mass., 208.
Woodward *v.* Worcester, 121 Mass., 245.
Middlesex Co. *v.* Lowell, 149 Mass., 509.
Merrifield *v.* Worcester, 110 Mass., 216.[a]

Missouri:

The Joplin Consolidated Mining Co. *v.* City of Joplin, 124 Mo., 129.

New Hampshire:

Vale Mills *v.* Nashua, 63 N. H., 136.

New Jersey:

Doremus *v.* Paterson, 65 N. J. Eq., 711.
State *v.* Freeholders of Bergen, 1 Dick., 173
Atty. Gen. *v.* City of Paterson, 45 Atl. (N. J., 1900), 995; 60 N. J. Eq., 385.

New York:

Butler *v.* Village of Edgewater, 6 N. Y. S., 174.
Chapman *v.* City of Rochester, 110 N. Y., 273.

Pennsylvania:

Good *v.* Altoona City, 162 Pa. St., 493.

EXCERPTS FROM IMPORTANT DECISIONS.

In Owens *v.* Lancaster City (182 Pa. St., 257, and 193 Pa. St., 436) the right of a city to use a stream passing through it as an open sewer, subject only to liability for any injury done to adjoining property through its negligence, seems to be conceded.

As to the limits of this right, and the consequences for which the municipality would be liable in the State of Pennsylvania, see the following cases:

The city was held liable for injury done to plaintiff's wharf by deposits from a sewer, in Butcher's Ice and Coal Company *v.* Philadelphia. (156 Pa. St., 54.)

It was held liable to a lot owner for maintaining a sewer mouth upon his lot, in Harris *v.* City. (155 Pa. St., 76.)

It was held liable for destroying the value of wells, caused by the flowing of polluted river water into them by underground passages, in Good *v.* Altoona. (162 Pa. St., 493.)

It was held liable for damages caused by accumulations of filth, ashes, or other material, that obstruct the flow of the water and throw

[a] In Merrifield *v.* Worcester damages were refused to a riparian owner who sued in tort for the pollution of his stream. The decision turned upon the nonliability of municipal corporations for the consequences of the judicial acts of their governing bodies. It holds that the plaintiff might recover for injury caused by pollution due to the improper construction or unreasonable use of the sewers, or to the negligence or other fault of the defendant in the care and management of them. It is no authority for the principle established in Indiana in Valparaiso *v.* Hagen.

it out upon the lands of adjoining owners, in Blizzard *v.* The Borough of Danville. (175 Pa., 479.)

In Owens *v.* Lancaster City (182 Pa. St., 257), at page 262, Mr. Justice Green remarks, obiter: "We apprehend the same principle would apply to the injury inflicted by allowing offensive and injurious odors and smells to issue from the polluting substances discharged into the stream from the city sewers."

Nolan *v.* New Britain (69 Conn., 668) was an action for damages caused by the defendant's discharge of its public sewers into a stream called Pipers Brook, which ran through plaintiff's land.

The city had, in 1872, under alleged legislative authority, condemned and taken, and condemned the right to take, occupy, and appropriate Pipers Brook for sewer purposes, but plaintiff did not appear in the proceedings, nor was any award made to him.

Significant excerpts from the supreme court's opinion, by Andrews, C. J., are here given:

> The use of Pipers Brook which the complainant charges that the defendant has made, unless there is a lawful warrant therefor, causes a public nuisance. * * * That it would be a public nuisance to render the water of a stream so impure that it could not be used for domestic purposes or for watering cattle, and so that it gave off noxious and unhealthy odors is hardly open to question (Chapman *v.* Rochester, 110 N. Y., 273), for the reason that these causes would injuriously affect every riparian owner along the whole length of the stream and every person who lived near it. If a municipal corporation, in the absence of a legal right to do so, causes sewage to pollute a water course, to the use of which a lower owner through whose premises the water course flows is entitled, it is guilty of a nuisance for which damages may be recovered. [Many authorities cited.]

On page 681, after an examination of the alleged statutory authority, the opinion continues:

> If it had been the intent of the legislature by the act of 1872 to authorize the common council of the city of New Britain to take or to affect any lands outside of the city limits, it is certain there would have been in the act some provision for the ascertainment of damages to be paid to the landowner. The right of the plaintiff to have the water of Pipers Brook flow through his land as it had been accustomed to flow (i. e., pure and uncontaminated) is not an easement, but is inseparably annexed to the soil. (Wadsworth *v.* Tillotson, 15 Conn., 366, 373.) To deprive the plaintiff of that part of his soil for the purposes named in that act would be the taking of private property for public use, and the plaintiff would be entitled to have just compensation.

As the complainant lived outside the city limits, it was held that he was in no way affected by the assessment proceedings.

The other defenses amounted to a claim of right to such use of the stream by prescription. As to this defense the court says, at page 683:

> The sixth defense presents the question of prescription. We have already indicated our opinion that the use of Pipers Brook of which the plaintiff

plains is a public nuisance. We suppose the law to be so that a public nuisance can not be prescribed for. No length of time can legitimate, or enable a party to prescribe for, a public nuisance. (People *v.* Cunningham, 1 Denio., 524; Mills *v.* Hall, 9 Wend., 315; Veazie *v.* Dwinel, 50 Me., 479, 490; Commonwealth *v.* Upton, 6 Gray, 471, 476; Wood on Nuisances, 722; 19 Am. and Eng. Encyc. of Law, 30.) When an action is brought by a party who has suffered a special injury in consequence of a public nuisance, a prescriptive right to do the acts complained of can not be maintained against him. (Bowen *v.* Wendt, 103 Cal, 236; People *v.* Gold-Run, etc., Mining Co., 66 Cal., 138; Boston Rolling Mills *v.* Cambridge, 117 Mass., 396; O'Brien *v.* St. Paul, 18 Minn., 176; Cooley on Torts, 614.) There is no occasion to discuss this defense further, because the defendant's counsel in their brief expressly disclaim that any right can be obtained by prescription to commit such a nuisance.

In Morgan *v.* City of Danbury (67 Conn., 484) the question of restraining a city from polluting the water of a stream by sewage, at the suit of a mill owner below the city, was thoroughly discussed, and the injunction sustained. The opinion is written by Baldwin, J., and the important portions of it are as follows (p. 493):

The nuisance thus complained of consisted, then, of discharging into a river, above the plaintiff's premises, certain substances of a kind and in such a manner that the water came to him polluted, and a deposit was made upon his land and in his mill pond whereby noxious odors were created, dangerous to his health and that of others, his dam partly filled up by filth, and the use and value of his property largely taken away—injuries which the defendant intended to increase by enlarging its sewer system, and adding to the amount of the deposits made from the sewers in the river, the result of which would be to fill up his mill pond with filth and sewage, and make his property valueless.

These allegations were denied, but they have been found true, and there is nothing inconsistent with their truth in the special finding of facts. They stated that the deposits from the sewers both filled up the plaintiff's mill pond, and polluted the air he breathed and the waters that flowed over his property. These, though proceeding from the same act, produced separate injuries. A nuisance was created with a double aspect. That to the waters of the stream and the air above it it was found constituted a public nuisance, though it was one which also wrought a special and peculiar injury to the plaintiff. That from filling up the mill pond constituted simply a private nuisance. (Haskell *v.* New Bedford, 108 Mass., 208, 216; Brayton *v.* Fall River, 113 Mass., 218, 229.) It was proper that the injunction should be so framed as to protect the plaintiff against every serious and irreparable injury which he might suffer by the continuance of the nuisance, and its terms are fully conformable to the claims stated in his complaint.

The defendant contends that the decree is too broad, in that it restrains the discharge into the river of any sewage, even if not of a noxious or polluting character, or though entirely and permanently disinfected and purified.

The primary meaning of "sewage" is that which passes through a sewer (Century Dictionary; Webster's International Dictionary). A secondary meaning is derived from the usual character of the contents of a sewer, and as used in that sense the word signifies the refuse and foul matter, solid or liquid, which it so carries off.

In the plaintiff's complaint the connection in which the term is employed is such as to indicate that it was intended to carry the secondary meaning.

And further, at page 496:

The defendant urges that it should not be made responsible for the acts of others, and that if its sewage is thoroughly disinfected, sterilized, and purified before its discharge into the river nothing further should be required, even though as it flows down the stream it may be brought into contact with other substances in such a way as to work a nuisance. But the right to deposit a thing in any place must always be dependent not only on its own nature but on the nature of the place in question and the uses to which that has already been put. A lighted match may be safely thrown into a brook under ordinary circumstances, but not should it happen to be covered with oil from a leaky tank.

If different parties by several acts foul the same stream, each may be enjoined against the commission of the wrong with which he is individually chargeable.

And see, also, Watson *v.* Town of New Milford (72 Conn., 561); Platt Bros. & Co. *v.* Waterbury (72 Conn., 531); and note on "Rights of municipal corporations to drain sewage into waters," appended to a report of the last-named case in 48 Lawyers' Rep. Annotated, page 691.

In Mayor, etc., of Birmingham, *v.* Land (34 So. Rep., 613), decided by the supreme court of Alabama in June, 1903, the Connecticut cases above cited were followed. Among other things, the court, per McClellan, C. J., say:

The fact that the city of Birmingham had statutory authorization to construct a sewer emptying into Valley Creek, upon the condemnation of lands taken or injured in its construction and use, is not of importance, since the lands here injured have not been condemned. The nuisance is none the less a nuisance because of the statutory power referred to, the right to exercise the power in respect of this land not having been acquired. City of Mansfield *v.* Balliett (65 Ohio St., 451; 58 L. R. A., 628, and note).

See, to the same effect, Sammons *v.* City of Gloversville (67 N. E. Rep., 622), decided by the court of appeals of New York, June 9, 1903. In this case an injunction was granted, its operation being suspended to enable the defendant to obtain legislative relief, or to abate the nuisance.

In Middlesex Company *v.* Lowell (149 Mass., 509), decided in 1889, it was held that an injunction should be granted to restrain defendant from discharging sewage into plaintiff's mill pond, and that no right to do so could be acquired by prescription.

This places Massachusetts in line with the other States, notwithstanding the decision in Merrifield *v.* Worcester that a city is not liable for damages caused by lawfully laying out and constructing and reasonably using a system of sewers in accordance with plans adopted by the proper corporate body, upon the principle that such body acts quasi judicially in so adopting plans.

In Butler *v.* Village of White Plains (69 N. Y. Supp., 193; N. Y. Sup. Court App. Div., 2d Dept., March, 1901), an injunction was

granted against a nuisance caused by the deposit of the effluent of defendant's sewage in the Bronx River. The fact that others were polluting the stream was no defense.

Grey, Attorney-General, *v.* Paterson (13 Dick., 1; on appeal, 15 Dick., 385), was an action brought by riparian owners below Paterson for an injunction restraining the city of Paterson from depositing or discharging its sewage through its drains or sewers into the Passaic River, and from constructing new sewers to discharge into said river, and from enlarging or increasing its present sewerage system with outlets into said river.

By an act passed in 1867 (P. L. of 1867, p. 653, sec. 17) Paterson had been authorized by the legislature as follows:

> That the mayor and aldermen of the city of Paterson are hereby authorized to cause such surveys, maps, and returns to be made as may be necessary to enable them to prescribe and adopt, either for the whole or any part of said city, the location of streets and sewers, or either, and the width thereof, hereafter to be opened or constructed therein, and when such location, width, and grade shall be adopted, the surveys, maps, and returns prescribing and defining the same shall be recorded in the clerk's office of the county of Passaic, and thereupon no street or sewer shall thereafter within the district comprised in any such survey, map, or return be opened or constructed, except in conformity therewith as to location, width, and grade, and fully to accomplish the purposes contemplated by this section the said mayor and aldermen may employ such engineers, surveyors, and other persons, and provide for their compensation and pass such ordinances as they may deem to be proper, and may enter upon any land for making surveys and examinations.

On the 26th of February, 1868, Paterson was further authorized to construct sewers and drains (P. L., 1868, p. 126). The second section provides:

> That all such sewers and drains shall be constructed in conformity with the plans thereof adopted or which shall be adopted by said mayor and aldermen pursuant to the seventeenth section of the act approved April 4, 1867, entitled "A further supplement to the act entitled 'An act amending and revising the act to incorporate the city of Paterson.'"

It was found by the court that, so far as the authority of the State can avail for that purpose, the legislative consent, in this case, furnishes ample protection to the city for the appropriate exercise of the power granted.

It was further said that riparian owners below the point where the tide ebbs and flows were not entitled to an injunction, because the title to their lands did not extend below high-water mark.

The title of owners above the ebb and flow of the tide extends to the middle of the stream, subject only to the rights of the public for purposes of navigation; and it is held that, notwithstanding the legislative grant of authority, such owners can not be deprived of their

ight of property in the river without just compensation. Following he case of Beach *v.* Sterling Iron and Zinc Company (9 Dick., 65), as ffirmed in 10 Dick., 824, it was decided that the owners above tide vater were entitled to compensation, but in view of the great detriment to the city if an injunction should be granted and the comparatively small injury done to the owners the injunction was refused, xcept in the alternative that the city should refuse to make such ompensation for the diminished value of their lands as shall be ascertained to be just.

In this case there is no recognition of the damage done to the lands adjoining or near the stream. The complainant's right to redress arises wholly from the injury done to the water, in which they have a proprietary right.

In Winchell *v.* Waukesha (110 Wis., 101), Dodge, J., gave the opinion, which in part is as follows:

The findings and evidence disclose a very obvious nuisance, which, if created and maintained by an individual, would entitle the plaintiff to the aid of a court of equity to effect its abatement, and to damages if pecuniary injury be established, with the decisions of this court. * * * It has been declared by this court in Harper *v.* Milwaukee (30 Wis., 365, 372), that "the general rule of law is that a municipal corporation has no more right to erect and maintain a nuisance than a private individual possesses, and an action may be maintained against such corporation for injuries occasioned by a nuisance for which it is responsible in any case in which, under like circumstances, an action could be maintained by an individual." Again, in Hughes *v.* Fond du Lac (73 Wis., 380, 383) it is said: "A municipal corporation is no more exempt from liability in case it creates a nuisance, either public or private, than an individual." These statements are very broad, and, appellant insists, must yield to various exceptions and limitations (pp. 105 and 106).

When, if ever, the legislature shall enact that streams generally or any stream shall be used as sewers without liability to the owners of the soil through which they run, the question of constitutional protection to private rights may be forced upon the courts for decision. Until such enactment is made, however, in clear and unambiguous terms, we shall be slow to hold by inference or implication that it has been made at all. The right of the riparian owner to the natural flow of waters, substantially unimpaired in volume and purity, is one of great value, which the law nowhere has more persistently recognized than in Wisconsin. Not alone the strictly private right, but important public interests, would be seriously jeopardized by promiscuous pollution of our streams and lakes. Considerations of aesthetic attractiveness, industrial utility, and public health and comfort are involved. Amid this conflict of important rights, we can not believe that the legislature concealed, in words merely authorizing municipalities to raise and expend money for the construction of sewers, a declaration of policy that each municipality might, in its discretion, without liability to individuals, take practical possession of the nearest stream as a vehicle for the transportation of its sewage in a crude and deleterious condition. At that stage in its logic we can not agree with the Indiana court in Valparaiso *v.* Hagen (153 Ind., 337).

STATUTORY RESTRICTIONS OF WATER POLLUTION.

CLASSIFICATION.

Speaking generally, jurisdiction over the pollution of waters in the United States is confined to the several States. There is no provision in the Constitution which gives to Congress authority in the premises, partly, no doubt, because at the time of its adoption the great importance of the subject from an interstate point of view was not thought of. Hence, by the familiar principle that the several States retain full sovereign powers except so far as such powers are restricted by the National Constitution or expressly delegated thereby to the National Government, the States have full control of this subject. In reviewing these laws, accordingly, we must examine the statutes of all the States and Territories.

Uniformity of legislation is not to be expected. The natural conditions existing in different portions of the vast territory are so various, the density of population differs so widely in the different sections involved, and public enlightenment as to the deleterious effects of water pollution and the necessity to restrain it is, in sparsely settled districts, so far behind that which has been developed in congested areas by the terrible consequences, that statutory regulations must necessarily differ. In some States there is found nothing more than a simple provision making it a crime to poison wells and springs, while others have made elaborate provisions designed to check and, so far as possible, absolutely to prevent all pollution of waters by mingling with them the refuse products of animal life or the wastes of human industry. If, therefore, we are to avoid making this review a mere catalogue of statutes, it will be necessary to adopt some system of classification and grouping. Doubtless a mere citation of the statutes of all the States, taken in their alphabetical order, would serve a useful purpose in enabling the reader to turn to the particular section in which his interest lies and to find the legislation which affects this section. But if, by a logical grouping of States according to their progress in this particular, we can give a clearer idea of the status of such legislation as a whole, without seriously interfering with the usefulness of the book as a compendium of State laws upon this subject, much will be gained.

Accordingly, I have arranged the States and Territories in three groups or classes, placing those in each group in alphabetical order for convenience of reference.

CLASS I. STATES WITH PARTIAL RESTRICTIONS.

This group comprises those States and Territories in which the ;islature has confined itself to forbidding the poisoning or pollution drinking water in certain ways or in certain localities. They ong in the same category because they are all at the same stage of owth in sanitary education—i. e., there is manifest in their legisla- n no sense of the general desirability of pure natural waters, but ly a desire to prevent certain acts recognized as criminal in intent as likely to injure special groups of persons (public or private cor- rations) whom the legislature desires to protect.

An alphabetical list of the States and Territories in Class I, with statutes in force in each at the close of 1905, either given in full abstracted so as to show their nature and force, is here presented.

ALABAMA.

[Acts of Alabama, 1896–97, p. 1281.]

ACT to punish any person who pollutes or contaminates water supplied to cities and towns of the State.

SECTION 1. *Be it enacted by the general assembly of Alabama*, That shall be unlawful for any person to knowingly deposit any dead ani- l or nauseous substance in any source, standpipe, or reservoir from ich water is supplied to any city or town of said State. Any per- n violating the provisions of this act shall be guilty of a misde- anor, and upon conviction shall be punished by a fine not exceeding 00 and may be sentenced to hard labor for the county not exceeding e year.

Approved, February 17, 1897.

[General Acts, Alabama, 1903, Act No. 542, p. 499.]

ACT to amend, reconstruct, and provide for the enforcement of the laws relating to the public health.

SEC. 15 (p. 508). Whenever complaint shall be made in writing to a alth officer of a county, city, or town that there is in any pond, lake, stream owned or maintained by a private individual or corporation y source of infection, or unsanitary condition, which is prejudicial the public health, or likely to become so, or any material or thing at is grossly offensive or indecent, it shall be the duty of such alth officer to thoroughly investigate such complaint. If upon vestigation said health officer shall be of the opinion that said com- aint is well founded, he shall at once notify the person responsible erefor that he must remove or abate, at his own expense, said source infection, unsanitary condition, or grossly offensive or indecent

material or thing. Should such person responsible for said nuisance refuse or neglect to obey such order, said officer shall refer the matter to the county board of health for investigation, and either party to the contest may request the State health officer to be present and participate in the investigation. Should said county board of health agree with the opinion of said health officer, and should the person responsible for said nuisance or for said indecent material or thing still refuse or neglect to comply with the decision reached by said county board of health, the health officer to whom said complaint was first made shall proceed with as little delay as possible to cause said source of infection, unsanitary condition, or grossly offensive material or thing to be removed or abated at the expense of the person responsible therefor.

ARKANSAS.

[Sandel and Hill's Digest, 1894.]

SEC. 1903. The throwing or dragging of dead animals, or animals in a dying condition, into any running stream or other body of water in this State is a misdemeanor.

Anyone violating the provisions of this chapter, on conviction thereof, shall be fined in any sum not less than ten nor more than fifty dollars. (Act March 27, 1891.)

[Laws of 1895, Act CXXVI, p. 183.]

AN ACT authorizing municipal corporations and other corporations to exercise certain privileges, and for other purposes.

SEC. 7. If any person shall * * * commit such a nuisance in or near the impounding dams or reservoirs of any water plant, or shall pollute the water or effect [affect] its wholesome qualities, he shall be deemed guilty of a misdemeanor and be fined for each and every offense in any sum not exceeding $200.

[Sandel and Hill's Digest, sec. 5134.]

They [municipal corporations] shall have the power to provide a supply of water by constructing or acquiring, by purchase or otherwise, wells, pumps, cisterns, reservoirs, or waterworks; to regulate the same; to prevent the unnecessary waste of water; to prevent the pollution of the water and injury to the waterworks; and for the purpose of establishing or supplying waterworks any municipal corporation may go beyond its territorial limits; and its jurisdiction to prevent or punish any pollution or injury to the stream or source of water, or to the waterworks, shall extend five miles beyond its corporate limits. [As amended by laws of 1903, act 88, p. 152.]

DELAWARE.

[Laws of 1893, p. 1024.]

AN ACT to amend chapter 242, volume 19, of the Laws of Delaware, entitled "An act to provide for the lighting of Middletown."

SEC. 10 (p. 1029). That if any person or persons shall designedly or maliciously injure the said light and water works, or obstruct the water to and from the same, or in any manner pollute the water supply * * * they shall forfeit and pay to the commissioner of the town of Middletown a fine not exceeding one hundred (100) dollars, to be recovered, etc.

FLORIDA.

[Revised Statutes of Florida, approved January 8, 1891.]

SEC. 2658. *Poisoning food or water.*—Whoever mingles any poison with food, drink, or medicine, with intent to kill or injure another person, or wilfully poisons any spring, well, or reservoir of water with such intent, shall be punished by imprisonment in the State prison for life or any term of years.

SEC. 2665. *Corrupting or interfering with water supply.*—Whoever wilfully or maliciously defiles, corrupts, or makes impure any spring or other source of water or reservoir, or destroys or injures any pipe, conductor of water, or other property pertaining to an aqueduct, or aids or abets in any such trespass, shall be punished by imprisonment not exceeding one year or by fine not exceeding one thousand dollars.

GEORGIA.

[Laws of 1896, p. 84.]

No. 57. AN ACT to prohibit the poisoning of any spring, well, or reservoir of water, to provide a penalty for the violation of the same, and for other purposes.

SEC. 1. *Be it enacted by the general assembly of the State of Georgia, and it is hereby enacted by authority of the same,* That from and after the passage of this act any person who wilfully and wantonly poisons or procures another to poison any spring, fountain, well, or reservoir of water shall be deemed guilty of a felony, and on conviction therefor shall be imprisoned in the penitentiary for a term of not less than two nor more than twenty years.

SEC. 2. Repeals inconsistent laws.

Approved, December 19, 1896.

IDAHO.

[Penal Code, passed 1901.]

SEC. 4916. Every person * * * who wilfully poisons any spring, well, or reservoir of water is punishable by imprisonment in the State prison for a term not less than one nor more than ten years.

IOWA.

[Code of Iowa, annotated, 1897.]

SEC. 4979. *Throwing dead animals in stream, spring, etc.*—If any person throw, or cause to be thrown, any dead animal into any river, well, spring, cistern, reservoir, stream, or pond, he shall be imprisoned in the county jail not less than ten nor more than thirty days or be fined not less than five nor more than one hundred dollars.

KANSAS.

[Laws of 1905, chap. 267, fish and game law.]

SEC. 6. It shall be unlawful for any person to empty or throw into or place in any lake, pond, river, creek, or stream, or other water within or bordering on this State, any acid, drug, lime, or other deleterious substance, or fishberries, or dynamite, giant powder, or other explosive matter of whatever kind, or any material or liquid which may kill, stun, poison, or craze fish; provided, that nothing in this section shall be construed to prevent the proper use of explosives for the exclusive purpose of improving navigation, or for blasting rock on [in] preparing foundations, or other improvements on or along the streams or waters of the State.

KENTUCKY.

[Compilation by John D. Carroll, 2d ed., 1899.]

SEC. 1278. If any person shall cast or place the carcass of any cattle or that of any other dead beast in any water course or within twenty-five yards thereof, or shall cast the same into any spring, or into any pond, such person, for every such offence, shall be fined for the first offense not less than five nor more than twenty dollars, and every subsequent offense not less than twenty nor more than one hundred dollars. (Under head of "Offences against public health.")

LOUISIANA.

[Revised Laws (Wolff).]

SEC. 924. Amending law of 1882, page 109.

Makes it an offense to "throw or cause to be thrown or conveyed into any navigable stream, bay, or lake within this State, bagasse from sugar mills, ballast from vessels, sinking timber of any kind, or any other matter of a nature to form an obstruction to its free navigation."

MICHIGAN.

[Compiled Laws of the State of Michigan (Lewis M. Miller).]

SEC. 11496. Willfully poisoning spring, well, or reservoir made a crime.

SEC. 2806. The council (of any village located upon or adjacent to any of the navigable waters of this State) shall have authority to "provide by ordinance for the preservation of the purity of the waters of any harbor, river, or other waters within the village," and other powers.

SEC. 3146. The council (of any city located upon or adjacent to any of the navigable waters of the State) "shall have authority to provide by ordinance for the preservation of the purity of the waters of any harbor, river, or other waters within the city, and within one-half of a mile from the corporate boundaries thereof; to prohibit and punish the casting or depositing therein of any filth, logs, floating matter, or any injurious thing," and other powers.

[Public Acts, 1899, No. 80, p. 115.]

AN ACT to prevent and punish the pollution and contamination of the waters of the stream known as Wolf Creek, in Lenawee County, Michigan, and the tributaries thereof.

The people of the State of Michigan enact:

SECTION 1. It shall be unlawful for any person or persons to wilfully or in any other manner knowingly to befoul, pollute, contaminate in any manner, so as to render said water offensive for drinking purposes, the waters of that stream situated in the townships of Adrian, Rome, and Cambridge, Lenawee County, Michigan, and known commonly as Wolf Creek, or any tributary thereof situated in said county, at any place in said stream above the dam from which the water supply of the city of Adrian is taken.

SEC. 2. Whoever mischievously, maliciously, or wilfully puts any dead animal, carcass or part thereof, or any other putrid, nauseous, noisome, or offensive substance in said stream or its tributaries, or in any other manner befouls the waters of said stream or its tributaries in an unwholesome or offensive manner, or shall drain the contents of any barnyard, waste factory products, or other unwholesome substance, into the water of said stream or its tributaries, shall be deemed guilty of a violation of this act.

SEC. 3. Any person convicted of a violation of this act shall be punished by a fine not exceeding one hundred dollars and not less than five dollars and costs of prosecution, and in default of the payment of said fine and costs he shall be imprisoned in the jail of Lenawee County not less than ten nor more than ninety days, or both such fine and imprisonment, in the discretion of the court.

This act is ordered to take immediate effect.

Approved, May 17, 1899.

[House Enrolled Act No. 404.]

AN ACT in relation to the pollution of the waters of Pine River in the counties of Midland and Gratiot, and Cass River in the county of Tuscola.

SEC. 1. It shall be unlawful for any person, firm, or corporation, except municipal corporations, or any agent or employe of such firm or corporation to pollute the waters of Pine River in the counties of Midland and Gratiot, and Cass River in the county of Tuscola, by depositing or attempting to deposit therein any beet pulp or other waste matter of any kind or character liable to decomposition.

SEC. 2. Any person, firm, or corporation, or any agent or employe of such firm or corporation, found guilty of a violation of this act shall be punished by a fine of not less than one hundred fifty dollars, or more than three hundred dollars, or by imprisonment in the county jail for not less than three months nor more than six months, or by both such fine and imprisonment in the discretion of the court.

MISSISSIPPI.

[Annotated Code of the General Statute Laws (Thompson, Dillard & Campbell).]

SEC. 1326 (under "Crimes and misdemeanors"). If any person shall in any manner permanently obstruct any of the navigable waters, or shall place any obstruction therein and not remove the same within a reasonable time, or if any person shall pollute any such waters by putting therein the carcass of any dead animal, or any refuse or foul matter, or any matter or thing calculated to render the water thereof less fit for drink or the sustenance of fish, the person so offending, in either case, shall be guilty of a misdemeanor, and, on conviction, shall be punished by a fine of not more than fifty dollars, or by imprisonment in the county jail not more than thirty days, or both; but this shall not apply to the Mississippi or Yazoo rivers.

[Amended; Laws of 1898, chap. 89, p. 101.]

Exception of Mississippi and Yazoo rivers dropped out, and the following clause added: "But this act shall not be so construed as to prevent any city or town in this State from constructing sewers so as to empty into any navigable streams of water in this State." (Approved February 10, 1898.)

NEBRASKA.

[Compiled Statutes of Nebraska, 1897.]

SEC. 6892 (Criminal Code, sec. 229). *Putting offensive matter into well or spring.*—If any person or persons shall put any dead animal, carcass, or part thereof, or other filthy substance, into any well, or into any spring, brook, or branch of running water, of which use is

made for domestic purposes, every person so offending shall be fined in any sum not less than two nor more than forty dollars.

SEC. 6893 (230). If any person or persons shall put the carcass of any dead animal, or the offals from any slaughterhouse or butcher's establishment, packing house, or fish house, or any spoiled meats or spoiled fish, or any putrid animal substance, or the contents of any privy vault, upon or into any river, bay, creek, pond, canal, road, street, alley, lot, field, meadow, public ground, market space, or common * * * he shall be fined in any sum not less than one nor more than fifty dollars.

NORTH DAKOTA.

[Revised Codes of North Dakota, 1899.]

SEC. 7291 (Penal Code, sec. 435). *Fouling water with gas tar.*—Every person who throws or deposits any gas tar or refuse of any gas house or factory into any public waters, river, or stream, or into any sewer or stream emptying into any such public waters, river, or stream, is guilty of a misdemeanor.

[Chap. 69. Fouling the public waters of this State.]

SEC. 7653. *Fouling public waters.*—Every person who deposits or places or causes to be deposited or placed any dead animal, offal, or other refuse matter offensive to the sight or smell or deleterious to health upon the banks or in the waters of any lake or stream, so far as the same is within the jurisdiction of the State is guilty of a misdemeanor, and upon conviction thereof is punishable by a fine of not less than twenty and not exceeding one hundred dollars.

SEC. 7654. *Extent of last section.*—The provisions of the last section shall be construed to include privies and privy vaults and any stable, shed, pen, yard, or corral wherein is kept any horse, cattle, sheep, or swine and located nearer than sixty feet from the top of the bank of such lake or stream, and also any slaughter house, grave, graveyard, or cemetery located nearer than eighty feet therefrom. But the provisions of said section shall not be construed to prevent any incorporated city within this State from running its sewers into any river: *Provided*, That where there is a dam across said river within the corporate limits of any such city, any such sewer shall connect with such river below such dam.

OKLAHOMA.

[Wilson's Revised and Annotated Statutes of Oklahoma, vol. 1, p. 894.]

SEC. 3732. From "An act to prevent public nuisances and fixing penalties for maintaining the same."

SEC. 16. It shall be unlawful for any person or persons or corporations to put any dead animal, carcass, or part thereof into any well, spring, brook, or branch of running water of which use is made for domestic purposes. Every person or persons so offending shall, on conviction thereof, be fined in any sum not less than five nor more than one hundred dollars.

SEC. 3733. Any person or persons or corporations who shall put any dead animal or any part of the carcass of a dead animal into any river, creek, or pond shall, upon conviction thereof, be fined in any sum not less than two nor more than twenty-five dollars.

SEC. 2344. Every person who throws or deposits any gas tar or refuse of any gas house or factory into any public waters, river, or stream, or into any sewer or stream emptying into any such public waters, river, or stream is guilty of a misdemeanor.

RHODE ISLAND.

[Revision of 1896, sec. 16, p. 977.]

OFFENCES AGAINST THE PERSON.

SEC. 16. Every person who shall mingle any poison with any food, drink, or medicine, with intent to kill or injure any person, and every person who shall wilfully poison any spring, well, or reservoir of water with such intent shall be imprisoned for life or for any term of years.

[Laws of Rhode Island, 1904, chap. 1222, p. 33.]

AN ACT for the better protection of the shell fisheries in the public waters of this State.

SEC. 1. No person shall deposit in, or allow to escape into, or shall cause or permit to be deposited in, or allowed to escape into any of the public waters of this State any substance which shall in any manner injuriously affect the growth of the shellfish in or under said waters, or which shall in any manner affect the flavor or odor of such shellfish so as to injuriously affect the sale thereof, or which shall cause any injury to the public and private fisheries of this State.

SEC. 2. Any person violating any of the provisions of this act shall, upon conviction thereof, be fined not less than five hundred dollars or more than two thousand dollars, one-half thereof to the use of the complainant and one-half thereof to the use of the State: *Provided*, That in case of conviction upon prosecution by the commissioners of shell fisheries the whole of any fine imposed shall go to the use of the State.

SEC. 3. Every person violating any of the provisions of this act shall be liable to pay to the party injured by such violation double

the amount of damages caused thereby, to be recovered in an action of the case in any court of competent jurisdiction. It shall not be necessary, before bringing suit for the recovery of such damages, for a criminal prosecution to have been first instituted for the violation of the provisions of this act, nor shall the recovery of damages under this section be a bar to such criminal prosecution.

SEC. 4. It shall be the duty of the commissioners of shell fisheries to investigate all complaints made to them of the violation of any of the provisions of this act. For the purpose of such investigation said commissioners may make examination of the premises, hold public hearings, summon witnesses, and take testimony under oath, and they shall have power to punish, by fine or imprisonment or both, all contempt of their authority in any hearing before them. They may employ professional or expert services as they may deem desirable.

SEC. 5. It shall be the duty of the shell fish commissioners to prosecute any person in their opinion guilty of the violation of any of the provisions of this act, and in all such prosecutions said commissioners shall not be required to enter into any recognizance or to give surety for costs. It shall be the duty of the attorney-general to conduct the prosecution of all cases brought by said commissioners under the provisions of this act. Complaints may also be brought and prosecuted by any citizen for any violation of its provisions.

SEC. 6. The expenses incurred by the commissioners of shell fisheries in the performance of the duties imposed upon them by this act shall be paid by the general treasurer out of any funds in the treasury not otherwise appropriated, upon the presentation of vouchers therefor duly certified by their chairman.

SEC. 7. All provisions of the General Laws, of the Public Laws, and of any special law inconsistent herewith are hereby repealed, and this act shall take effect upon its passage.

[Laws of Rhode Island, 1904, chap. 1178, p. 58.]

AN ACT to prevent pollution of the sources of the water supply of the cities of Pawtucket and Woonsocket and the towns of Bristol and East Providence.

SEC. 1. Section 1 of chapter 491 of the Public Laws is hereby amended so as to read as follows:

"SEC. 1. No person shall throw or discharge, or suffer to be discharged from land owned, occupied, or controlled by him, into any stream, pond, or reservoir used as a source of water supply by the city of Woonsocket, the city of Pawtucket, the city of Newport, the town of Bristol, the town of Warren, the town of East Providence, the town of Narragansett, the town of Jamestown, the East Greenwich fire district, or by any water company supplying water f domestic use in any of said cities or towns, or into any tributary

feeder of any such stream, pond, or reservoir, any sewerage, drainage, refuse, or noxious or polluting matter of such nature as will corrupt or impair the quality of the waters of said stream, pond, or reservoir, or render the same injurious to health, which water shall be of the recognized standard of purity to be determined by the State board of health or other recognized authority. But the provisions of this section shall not interfere with or prevent the enriching of land for agricultural purposes by the owner or occupant thereof if no human excrement is used thereon. Any person violating the provisions of this section shall be punished for each offence by a fine of fifty dollars or by imprisonment for not to exceed thirty days or by both such fine and imprisonment.

SEC. 2. Section 2 of chapter 491 is hereby amended so as to read as follows:

"SEC. 2. The State board of health or the secretary of said board, when satisfied that any sewerage, drainage, or refuse or polluting matter exists in a locality such that there is danger that said sewerage, drainage, or refuse or polluting matter may corrupt or impair the quality of said waters or render them injurious to health, may order the owner or occupant of the premises where said sewerage, drainage, or refuse or polluting matter exists to remove the same from said premises within such time after the serving of the notice prescribed in the next succeeding section as said board or secretary may designate; and if the owner or occupant neglects or refuses so to do he shall be fined twenty dollars for each day during which he permits said sewerage, drainage, or refuse or polluting matter to remain upon said premises after the time prescribed for the removal thereof."

SEC. 3. Section 3 of chapter 491 is hereby amended so as to read as follows:

"SEC. 3. Such notice shall be in writing, signed by the secretary of the State board of health or the person performing the duties of that official, and shall be served by any sheriff, deputy sheriff, or constable by reading the same in the presence or hearing of the owner, occupant, or his authorized agent, or by leaving a copy of the same in the hands or possession of, or at the last and usual place of abode of, said owner, occupant, or agent if within this State: *Provided, however*, That if said owner, occupant, or agent be a corporation incorporated in this State, said notice shall be served by leaving a copy thereof at the last and usual place of abode of the president or person performing the duties of president of said corporation. But if said premises are unoccupied, or the residence of the owner is unknown or without this State, or if the said owner is a corporation incorporated without this State, the notice may be served by posting a copy of the same on the premises and by advertising the same in some newspaper published in Providence County in such manner and for such length

of time as the State board of health or the Secretary thereof may determine."

SEC. 4. Section 4 of chapter 491 is hereby amended so as to read as follows:

"SEC. 4. The secretary of the State board of health, when so directed by said board, shall prosecute for all violations of this chapter and shall not be required to give surety for costs upon complaints made by him; but the cities of Woonsocket and Pawtucket and the towns of Bristol and East Providence shall be directly liable to the State for the costs incurred in the prosecution for violation of this chapter in their respective cases."

SEC. 5. Section 5 of chapter 491 is hereby amended so as to read as follows:

"SEC. 5. The appellate division of the supreme court, upon the application of the mayors of said cities or the presidents of the town councils of said towns, or upon the application of the secretary of the State board of health, may issue an injunction to enforce the orders of the State board of health, or the secretary thereof, provided for in this chapter."

SEC. 6. All acts and parts of acts inconsistent herewith are hereby repealed, and this act shall take effect upon its passage.

Passed April 12, 1904.

WISCONSIN.

[Wisconsin Statutes, 1898, p. 651.]

POWERS OF COUNCIL IN CITIES UNDER GENERAL LAW.

57. To provide for the preservation of any harbor within or of the city; prevent any use of the same or of such part of any lake, river, stream, spring, or pond as is within the city, or any action in relation thereto inconsistent with or detrimental to the public health or calculated to render the water of the same or any part thereof impure or offensive; or tending in any degree to fill up and obstruct the same; prohibit and punish the casting or depositing therein of any earth, dead animals, ashes, or other substance, or filth, logs, or floating matter. * * *

PRESERVATION OF PUBLIC HEALTH.

[Idem, p. 1065.]

SLAUGHTERHOUSES. SEC. 1418. No person shall erect, maintain, or keep any slaughterhouse upon the bank of any river, running stream, or creek, or throw or deposit therein any dead animal or any part thereof or any of the carcass or offal therefrom, nor throw or deposit the same into or upon the banks of any river, stream, or creek which

shall flow through any city, village, or organized town containing two hundred or more inhabitants, or erect, maintain, or use any building for a slaughterhouse within the limits of any village, incorporated or unincorporated, or at any place within one-eighth of a mile of any dwelling house or a building occupied as a place of business; and every person who shall violate any of the provisions of this section shall forfeit for each such violation not less than ten dollars nor more than one hundred dollars; and the mayor of the city, president of the village, and the chairman of the town in which any such slaughterhouse is located shall have the power to and shall cause the same to be immediately removed; and every such officer who shall knowingly permit any such slaughterhouse to be used or maintained contrary to the provisions of this section shall forfeit not less than fifteen dollars nor more than fifty dollars. In any county containing a population of one hundred thousand or over all the provisions of this section relating to slaughterhouses shall apply to all establishments and manufactories in which dead animals or any part thereof or any of the carcasses or offal therefrom are collected and converted into marketable products.

OFFENSES AGAINST LIVES AND PERSONS.

[Idem, p. 2669.]

SEC. 4384. *Poisoning food, drink, etc.*—Any person who shall mingle any poison with any food, drink, or medicine, with intent to kill or injure any other person, or who shall wilfully poison any spring, well, or reservoir of water with such intent, shall be punished by imprisonment in the State prison not more than ten years nor less than one year.

[Laws of Wisconsin, 1905, chap. 402.]

AN ACT to amend section 4567 of the statutes of 1898, as amended by chapter 325, laws of 1903, prohibiting depositing of deleterious substances in waters and providing a penalty.

SEC. 1. Section 4567 of the statutes of 1898, as amended by chapter 325, laws of 1903, is hereby amended by adding after the words, "decayed wood," where they occur in line 14 of chapter 325, laws of 1903, the words: "Sawdust, sawmill offal, and planing mill shavings;" also by adding after the word "paper" where it occurs in line 16 of chapter 325, laws of 1903, the words "beet sugar;" further amend by striking out the word "or" in line 20, all of lines 21, 22, 23, 24, and 25, and the words "mill shavings" in line 26 of chapter 325, laws of 1903; also further amend by adding after the word "mouth," where it occurs in line 30 of chapter 325, laws of 1903, the words "nothing in this section shall apply to the following streams: The Kickapoo River, the Pine River in Richland County, Balsam branch

in Polk County, the Chippewa River from mouth of Thornapple River to its mouth, Flambeau River from dam at Ladysmith to its mouth, Black River from Falls Dam down, in Jackson County, and the Wisconsin River from the north boundary line of the city of Rhinelander down to its mouth," so that said section 4567 when so amended shall read as follows:

"SECTION 4567. Any person who shall cast, deposit, or throw overboard from any row, sail, or steam boat or other craft into any of the inland waters of this State or into Green Bay, Sturgeon Bay, and Chequamegon Bay, or deposit or leave upon the ice thereof until it melts, any fish offal, which shall be construed to mean and include the head, intestines, blood, and cleanings of fish and dead fish, or throw or deposit or permit to be thrown or deposited any lime, tanbark, ship ballast, stone, sand, slabs, decayed wood, sawdust, sawmill offal, and planing-mill shavings, or any acids or chemicals or waste or refuse arising from the manufacture of pulp, paper, or beet sugar, or other substances deleterious to fish life (authorized drainage and sewage from municipalities excepted), into any of the rivers, lakes, or streams of this State, including Green Bay, Chequamegon Bay, Sturgeon Bay, or into any streams wherein there have been planted trout fry, or in which trout naturally abound, shall be punished by a fine of not less than twenty-five dollars nor more than one hundred dollars, or by imprisonment in the county jail not less than thirty days nor more than four months. (Nothing in this section shall apply to the following streams: The Kickapoo River, the Pine River in Richland County, Balsam branch in Polk County, the Chippewa River from the mouth of Thornapple River to its mouth, Flambeau River from dam at Ladysmith to its mouth, the Black River from the Falls Dam down in Jackson County, and the Wisconsin River from the north boundary line of the city of Rhinelander down to its mouth.) The fact of any fisherman coming to the shore with dressed fish in his boat and without the offal produced by such dressing shall be prima facie evidence of the violation of the first clause of this section."

SEC. 2. All acts or parts of acts inconsistent with or in conflict with the provisions of this act are hereby repealed.

SEC. 3. This act shall take effect and be in force from and after its passage and publication.

Approved, June 17, 1905.

CLASS II. STATES WITH GENERAL RESTRICTIONS.

This group consists of those States and Territories in which the importance of pure water for every inhabitant of the State or Territory for drinking and domestic purposes has received legislative

recognition. It will be noted that the laws are general in their appl cation, varying much in the elaborateness of the wording and in t emphasis laid upon the remedies and penalties provided for infra tions of the law.

This class logically includes all States not included in Class I, but inasmuch as certain States have recently adopted stringent and elab orate methods, novel and extraordinary in their character, to restor and protect the purity of their navigable and potable waters, these States have been omitted from Class II and are treated in a class by themselves, forming Class III (see p. 57).

CALIFORNIA.

[Penal code as in force at the close of the session of 1901.]

SEC. 374. *Putting dead animals in streets, rivers, etc.*—Every person who puts the carcass of any dead animal, or the offal from any slaughter pen, corral, or butcher shop into any river, creek, pond, reservoir, stream, street, alley, public highway, or road in common use, or who attempts to destroy the same by fire within one-fourth of a mile of any city, town, or village, except it be in a crematory, the construction and operation of which is satisfactory to the board of health of such city, town, or village; and every person who puts any water-closet or privy, or the carcass of any dead animal, or any offal of any kind in or upon the borders of any stream, pond, lake, or reservoir from which water is drawn for the supply of the inhabitants of any city, city and county, or any town in this State, so that the drainage for such water-closet, privy, or carcass, or offal may be taken up by or in such stream, pond, lake, or reservoir; or who allows any water-closet or privy, or carcass of any dead animal, or any offal of any kind to remain in or upon the borders of any such stream, pond, lake, or reservoir within the boundaries of any land owned or occupied by him, so that the drainage from such water-closet, privy, carcass, or offal may be taken up by or in such stream, pond, lake, or reservoir, or who keeps any horses, mules, cattle, swine, sheep, or live stock of any kind penned, corralled, or housed on, over, or on the borders of any such stream, pond, lake, or reservoir, so that the waters thereof become polluted by reason thereof, or who bathes in any such stream, pond, lake, or reservoir, or who by any other means fouls or pollutes the waters of any such stream, pond, lake, or reservoir is guilty of a misdemeanor, and upon conviction thereof shall be punished as described in section 377. (Commissioners' amendments, approved March 16, 1901; took effect July 1, 1901.)

SEC. 374½. *Discharging coal tar, etc., into waters.*—Every person, firm, association, or corporation which shall discharge or deposit, or

shall cause or suffer to be discharged or deposited, or to pass in or into the waters of any navigable bay or river in this State any coal tar or refuse or residuary product of coal, petroleum, asphalt, bitumen, or other carbonaceous material or substance is guilty of a misdemeanor, and for each offense is punishable by imprisonment in the county jail for not exceeding one year or by fine not exceeding $1,000 or by both such fine and imprisonment. (New section, approved March 25, 1901; took effect immediately. Statutes, 1901, p. 813.)

[Statutes of California, 1905, chap. CXXXV, p. 138.]

AN ACT to amend the penal code of the State of California by adding a new section thereto, to be numbered section 377b, making it a misdemeanor to refuse or neglect to conform to the rules, orders, and regulations of the State board of health, concerning the pollution of water, used or intended to be used for human or animal consumption:

SEC. 1. A new section to be numbered section 377b is hereby added to the penal code of the State of California, to read as follows:

377b. Any person who shall violate or refuse or neglect to conform to any sanitary rule, order, or regulation prescribed by the State board of health for the prevention of the pollution of springs, streams, rivers, lakes, wells, or other waters used or intended to be used for human or animal consumption shall be guilty of a misdemeanor.

SEC. 2. All acts and parts of acts inconsistent or in conflict with this act are hereby repealed.

SEC. 3. This act shall take effect immediately. (Act of March 18, 1905.)

[Statutes of California, 1905, Chap. CXXXVI, p. 138.]

AN ACT To amend the penal code of the State of California by adding a new section thereto, to be numbered section 377c, making it a misdemeanor to refuse or neglect to conform to the rules, orders, and regulations of the State board of health, concerning the pollution of ice used or intended for public consumption.

SEC. 1. A new section, to be numbered 377c, is hereby added to the penal code of the State of California, to read as follows:

377c. Any person who shall violate, or refuse or neglect to conform to any sanitary rule, order, or regulation prescribed by the State board of health for the prevention of the pollution of ice or the sale or disposition of polluted ice offered, kept, or intended for public use or consumption, shall be guilty of a misdemeanor.

SEC. 2. All acts and parts of acts inconsistent or in conflict with this act are hereby repealed.

SEC. 3. This act shall take effect immediately. (Act of March 18, 1905.)

COLORADO.

[Mills' Annotated Statutes, 1891, p. 949.]

SEC. 1376. *Polluting streams—penalty.*—If any person or persons shall hereafter throw or discharge into any stream of running water or into any ditch or flume in this State any obnoxious substance, such as refuse matter from slaughterhouse or privy, or slops from eating houses or saloons, or any other fleshy or vegetable matter which is subject to decay in the water, such person or persons shall, upon conviction thereof, be punished by a fine not less than one hundred dollars nor more than five hundred dollars for each and every offense so committed.

SEC. 1357 provides a penalty not exceeding five hundred dollars for anyone "who shall in anywise pollute or obstruct any water course, lake, pond, marsh, or common sewer, or continue such obstruction or pollution so as to render the same offensive or unwholesome," &c.

SEC. 3330 (p. 1861). *Emptying oil into the waters of the State a misdemeanor—penalty.*

AN ACT To prohibit the emptying or running of oil or petroleum, or other oleaginous substance into any waters of this State, and to impose a penalty for the violation of this act.

[Laws, 1889, p. 287, approved March 7, 1889, in force June 7, 1889.]

If any person or persons, corporation or corporations shall hereafter empty or cause to be emptied, or allow the emptying or flowing of oil, petroleum, or other oleaginous substance into any of the waters of this State, or deposit or cause the same to be deposited at such distance that the same may be carried into such waters by natural causes, such person or persons, corporation or corporations so offending shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine not exceeding one thousand dollars, or imprisonment in the county jail not exceeding six months, or both such fine and imprisonment, for each such offense.

ILLINOIS.

[Hurd's Revised Statutes, 1901, sec. 202, p. 627.]

Whoever willfully and maliciously defiles, corrupts, or makes impure any spring or other source of water or reservoir * * * shall be fined not exceeding one thousand dollars or confined in a county jail not exceeding one year.

Page 631, section 221, makes it a public nuisance—

1. To cause or suffer the carcass of any animal or any offal, filth, or noisome substance to be collected or deposited or to remain in any place to the prejudice of others.

2. To throw or deposit any offal or other offensive matter, or any carcass of any dead animal, in any water course, lake, pond, spring, well, or common sewer, street, or public highway.

3. To corrupt or render unwholesome or impure the water of any spring, river, stream, pond, or lake to the injury or prejudice of others.

INDIANA.

[Burns's Annotated Statutes, 1904.]

SEC. 2156. *Nuisance by dead animals.*—Whoever puts the carcass of any dead animal or the offal from any slaughterhouse or butcher's establishment, packing house, or fish house, or any spoiled meats or spoiled fish, or any putrid animal substance, or the contents of any privy vault upon or into any river, pond, canal, lake, public ground, market place, common, field, meadow, lot, road, street, or alley, and whoever, being the owner or occupant of any such place, knowingly permits any such thing to remain therein to the annoyance and injury of any of the citizens of the State, or neglects or refuses to remove or abate the nuisance occasioned thereby within twenty-four hours after knowledge of the existence of such nuisance upon any of the above described premises owned or occupied by him, or after notice thereof, in writing, from any health officer of the city or the trustee of the township in which such nuisance exists, shall be fined not more than one hundred dollars nor less than one dollar.

SEC. 2169. Whoever maliciously or mischievously puts any dead animal carcass or part thereof on, or any other putrid, nauseous, noisome, or offensive substance into, * * * or in any manner befouls any well, cistern, spring, brook, canal, or stream of running water, or any reservoir of waterworks of which any use is made or may be made for domestic purposes shall be fined not more than one hundred dollars nor less than five dollars, to which may be added imprisonment in the county jail not more than sixty days nor less than ten days.

(The foregoing section is repealed by the act of 1905 hereafter quoted.)

SEC. 3538. *Streams and ferries.*—The common council shall have exclusive power to keep open streams, and preserve, and, if necessary and expedient, change the course of rivers passing through or bordering upon the corporate limits of such city; to prevent encroachment or injury to the banks thereof, or the casting into the same of offal, dead animals, logs, or rubbish. * * *

[Acts of 1901, Chap. LXI, p. 96.]

AN ACT prohibiting the discharge of waste water and refuse of manufactur establishments into streams of water, conferring certain powers upon t State board of health in such cases, providing penalties for the violati thereof, and declaring an emergency.

SECTION 1. *Be it enacted by the general assembly of the State o Indiana*, That it shall be unlawful for any person, firm, or corpora tion owning or operating any manufacturing establishment to di charge or permit to be discharged into any stream of water any wa water or refuse from said factory of such character as to pollute sai stream, except by and in pursuance to a written permission so to do first obtained from the State board of health as hereinafter provided.

SEC. 2. Whenever any person, firm, or corporation owning o operating a manufacturing establishment shall file with the secre tary of the State board of health a verified application in writing, asking permission to be allowed to discharge into any stream any waste water or refuse from such establishment, and showing therein that the water of said stream is at such stage as that such refuse or waste water may be safely discharged into such stream without injury to the public, it shall be the duty of such board to inspect the said stream at and below the point of such proposed discharge, and if it is found that such refuse and waste water may be safely discharged therein without injury as aforesaid, the said board may, in its discretion, grant and issue a written permit allowing such discharge into said stream for a time to be limited therein, which permit shall be void and of no effect after the time so fixed, and may be revoked by said board at any time. The holder of any such permit regularly issued by such board shall be authorized to discharge any such refuse or waste water into such stream during the time fixed and limited in such permit, and shall not be liable therefor in any suit at law or in equity: *Provided*, That nothing herein contained shall prevent any person specially damaged by any such discharge from recovering the amount of such special damages so sustained in an action at law brought for such purpose.

SEC. 3. Any person, firm, or corporation violating any of the provisions of this act shall be fined in any sum not less than twenty-five dollars nor more than five hundred dollars.

SEC. 4. Whereas an emergency exists for the immediate taking effect of this act, the same shall be in force on and after its passage.

[Laws of 1905, chap. 169, p. 584.]

SEC. 553. *Befouling water.*—Whoever maliciously or mischievously puts any dead animal, carcass, or part thereof, or any other putrid, nauseous, noisome, or offensive substance into, or in any manner be-

ouls any well, cistern, spring, brook, canal, or stream of running water, or any reservoir of waterworks, of which any use is or may be made for domestic purposes, shall, on conviction, be fined not less than five dollars nor more than one hundred dollars, to which may be added imprisonment in the county jail not less than ten days nor more than sixty days.

SEC. 689. *Repeal.*—All laws within the purview of this act are hereby repealed; but this repeal shall not affect any prosecutions pending or offenses heretofore committed under existing laws, and such prosecutions and offenses shall be continued and prosecuted to a final determination, as if this act had not passed; nor shall this repeal affect the enforcement of any fine or penalty or other punishment provided as a punishment for the violation of any civil statute; nor shall this act be construed to repeal any act passed at this session of the general assembly.

(Approved March 9, 1905.)

MAINE.

[Laws of 1891, chap. 82, p. 67.]

AN ACT to protect waters used for domestic purposes.

SEC. 1.[a] Whoever knowingly and willfully poisons, defiles, or in any way corrupts the waters of any well, spring, brook, lake, pond, river, or reservoir used for domestic purposes for man or beast, or knowingly corrupts the sources of the water supply of any water company or of any city, town, or municipal corporation supplying its inhabitants with water, or the tributaries of said sources of supply, in such manner as to affect the purity of the water so supplied, or knowingly defiles such water in any manner, whether the same be frozen or not, or puts the carcass of any dead animal or other offensive material into said waters or upon the ice thereof, shall be punished by a fine not exceeding one thousand dollars or by imprisonment not exceeding one year.

SEC. 2. Whoever shall wilfully injure any of the property of any water company or of any city, town, or municipal corporation used by it in supplying water to its inhabitants shall be punished by a fine not exceeding one thousand dollars or by imprisonment not exceeding one year, and such person shall also forfeit and pay to such water company, city, or town three times the amount of actual damages sustained, to be recovered in an action of the case. (As amended by the laws of 1905, Chap. 93, p. 97.)

SEC. 3. Inconsistent acts repealed.

[a] As amended by laws of 1905, chap. 97, p. 100.

[Laws of 1903, Special Laws, chap. 94, p. 156.]

AN ACT to prevent the pollution of the waters of Sebago Lake.

SEC. 1. No person or corporation shall use or occupy any structure hereafter built upon or near the shores of Sebago Lake, in the county of Cumberland, or upon any of the islands of said lake for such purposes or in such manner that the sewage or drainage therefrom shall enter the waters of said lake or pollute the same.

SEC. 2. No sewage, drainage, refuse, or polluting matter of such kind and amount as either by itself or in connection with other matter will corrupt or impair the quality of the water of said Sebago Lake or render it injurious to health shall be discharged into said lake, but nothing herein shall prohibit the cultivation and use of the soil in the ordinary methods of agriculture if no human excrement is used thereon within three hundred feet of the shores of said lake.

SEC. 3. The supreme judicial court shall have jurisdiction in equity to enjoin, prevent, or restrain any violation of the provisions of this act.

SEC. 4. This act shall take effect when approved.

Approved February 26, 1903.

MARYLAND.

[Poe's Maryland Code, adopted March 14, 1888.]

RIVERS.

SEC. 240. If any ballast, ashes, filth, earth, soil, oysters, or oyster shells be taken, unladen, or cast out of any ship, steamboat, scow, pungy, or other vessel, on any pretense whatever, in the Chesapeake Bay above "Sandy Point," or in the waters of Herring Bay, or in any river, creek, or harbor within this State, below high-water mark, the master or other person having charge of such vessel shall, upon conviction thereof, be fined.

Waters of Potomac River above the canal dam near the mouth of Wills Creek are protected by section 242 against pollution calculated to render the waters of said river "impure or unfit for use."

WATER SUPPLY—POLLUTION OF SOURCES OF.

[Passed in 1886, chap. 6.]

SEC. 277. If any person shall put, or cause to be placed, any dead animal or part of the carcass of any dead animal, or any decayed or filthy animal or vegetable matter, into any stream, or the tributary of any stream, well, spring, reservoir, pond, or other source from which water or ice is drawn, taken, or used for drinking or domestic purposes, or shall knowingly suffer any sewage, washings, or other

offensive matters from any privy, cesspool, factory, trades establishment, slaughterhouse, tannery, or other place over which he shall have control, to flow therein, or into any drain or pipe communicating therewith, whereby the water supply of any city, town, village, community, or household is fouled or rendered unfit for drinking and domestic purposes, he shall be guilty of a misdemeanor and shall, upon conviction thereof in a court of competent jurisdiction, be fined not more than two hundred dollars for every such offence; and after reasonable notice, not exceeding fifteen days, from the State board of health, or any local sanitary authority, to discontinue the act whereby such water supply is fouled, a further sum of not more than fifty dollars for every day during which the offence is continued.

MISSOURI.

[Revised Statutes, 1899.]

CRIMES AND PUNISHMENTS.

SEC. 2234. *Putting dead animals in well, &c.*—If any person or persons shall put any dead animal, carcass, or part thereof, the offal, or any other filth into any well, spring, brook, branch, creek, pond, or lake, every person so offending shall, on conviction thereof, be fined in any sum not less than ten nor more than one hundred dollars. If any person shall remove, or cause to be removed and placed * * * in any of the streams and water courses other than the Missouri or Mississippi River, any dead animal, carcass, or part thereof, or other nuisance, to the annoyance of the citizens of this State, or any of them, every person so offending shall, upon conviction thereof, be fined for every such offence any sum not less than ten dollars nor more than fifty dollars, and if such nuisance be not removed within three days thereafter, it shall be deemed a second offence against the provisions of this section.

SEC. 2235. *Corrupting or diverting water supply.*—Whoever willfully or maliciously poisons, defiles, or in any way corrupts the water of a well, spring, brook, or reservoir used for domestic or municipal purposes, or whoever willfully or maliciously diverts, dams up, and holds back from its natural course and flow any spring, brook, or other water supply for domestic or municipal purposes, after said water supply shall have once been taken for use by any person or persons, corporations, town, or city for their use, shall be adjudged guilty of a misdemeanor and punished by a fine not less than fifty nor more than five hundred dollars, or by imprisonment in the county jail not exceeding one year, or by both such fine and imprisonment, and shall be liable to the party injured for three times the actual damage sustained, to be recovered by suit at law.

SEC. 1974. *Injury to schoolhouses and church buildings.*—Every person * * * who shall in any manner pollute the water contained in any well, cistern, or reservoir (in which water is gathered or kept for the supply of a schoolhouse or those attending the same) shall be guilty of a misdemeanor.

[Section 28 of House bill No. 15, laws of 1905, p. 163.]

AN ACT relating to the preservation, propagation, and protection of game animals, birds, and fish; creating the office of game and fish warden; creating a game protection fund, and appropriating money therefrom.

SEC. 28. It shall be unlawful for any person or persons, firm, or corporation to suffer or permit any dyestuff, coal tar, oil, sawdust, poison or deleterious substances to be thrown, run, or drained into any of the waters of this State in quantities sufficient to injure, stupefy, or kill fish which may inhabit the same at or below the point where any such substances are discharged or permitted to flow or thrown into such waters. Any person or persons, firm, or corporation offending against any of the provisions of this section shall be deemed guilty of a misdemeanor, and upon conviction shall be fined not less than $200.00 nor more than $500.00 for each offense.

Approved March 10, 1905.

NEVADA.

[General Statutes of Nevada.]

SEC. 4617. (Crimes and punishments, sec. 54.) * * * Every person who shall willfully poison any spring, well, or reservoir of water shall, upon conviction thereof, be punished by imprisonment in the State prison for a term not less than one nor more than ten years.

Sawdust in rivers.—It is made a misdemeanor to deposit sawdust in or on the waters of any lake, river, or running stream by laws of 1889, page 24, Chapter XV.

[Laws of Nevada, 1903, Chap. CXXII, p. 214.]

AN ACT to prevent the pollution or contamination of the waters of the lakes, rivers, streams, and ditches in the State of Nevada, prescribing penalties, and making an appropriation to carry out the provisions of this act. (Approved March 20, 1903.)

The people of the State of Nevada, represented in senate and assembly, do enact as follows:

SECTION 1. *Unlawful to pollute any body of water.*—Any person or persons, firm, company, corporation, or association in this State, or

the managing agent of any person or persons, firm, company, corporation, or association in this State, or any duly elected, appointed, or lawfully created State officer of this State, or any duly elected, appointed, or lawfully created officer of any county, city, town, municipality, or municipal government in this State, who shall deposit, or who shall permit or allow any person or persons in their employ or under their control, management, or direction to deposit in any of the waters of the lakes, rivers, streams, and ditches in this State any sawdust, rubbish, filth, or poisonous or deleterious substance or substances liable to affect the health of persons, fish, or live stock, or place or deposit any such deleterious substance or substances in any place where the same may be washed or infiltered into any of the waters herein named, shall be deemed guilty of a misdemeanor, and upon conviction thereof in any court of competent jurisdiction shall be fined in any sum not less than fifty dollars nor more than five hundred dollars, exclusive of court costs: *Provided*, That in cases of State institutions, municipalities, towns, incorporated towns or cities, when, owing to the magnitude of the work, immediate correction of the evil is impracticable, then in such cases the authorities shall adopt all new work, and as rapidly as possible reconstruct the old systems of drainage, sewerage, and so as to conform with the provisions of this act: *And provided further*, That all such new and reconstructed systems shall be completed within four years from the date of passage hereof: *Provided*, That nothing in this act shall be so construed as to permit mining or milling companies to dump tailings directly into any stream in this State so as to prevent or impede the natural flow of such stream. Nothing in this act shall be so construed as to apply to any quartz mill or ore reduction works in this State.

SEC. 2. For the purposes of this act the word "ditch" shall be construed to mean any ditch, canal, channel, or artificial waterway used for carrying or conducting water into any reservoir from which it may be used or distributed for domestic purposes to any person in this State, or to any person in any county, city, town, or municipality in this State.

SEC. 3. The sum of three thousand dollars is hereby appropriated out of any money in the State treasury, not otherwise appropriated, subject to the disposal of the governor of this State, for the purpose of enforcing the provisions of this act, either in the courts of this State or in the courts of the United States, such expenditure to be allowed and paid as other claims against the State are allowed and paid.

SEC. 4. This act shall take effect and be in force from and after the first day of July, A. D. nineteen hundred and four.

within this Territory, so as to render the same offensive or dangerous to the health of the inhabit munity or of any person having the right to use same, for drinking or domestic purposes, or that waters unfit or dangerous for watering stock, or fo horticultural purposes.

SEC. 55. That the polluting of waters in any of tl specified is hereby declared to be a public nuisanc immediately removed by the person or persons cr upon the demand of any public officer or of any p who may have a right to the use of said waters.

SEC. 56. That any person or persons violating any of sec. 54 may be tried therefor before any justice o county where the offence is committed, and upon c shall be punished by a fine in any sum not less tha more than one hundred dollars, or by imprisonment for any period of time not less than ten days nor days, or by both fine and imprisonment. And in ad justice of the peace shall direct the sheriff of the co stable of the precinct to relieve such nuisance, at tl person or persons creating the same, which said c taxed as other costs against the person or persons shall be collected in the manner provided by law for costs in criminal cases.

[Laws of 1899, chap. 79, p. 175.]

cans, paper, ashes, bones, or other garbage into any running stream, spring, lake, pond, reservoir, ditch, or water course, or to run or empty any sewer or other foul substance into the same, or in any other manner or means to pollute or foul the said water so as to render the same offensive or dangerous to the health of the inhabitants of any community or of any person having the right to use the same for drinking or domestic purposes, or that may render said waters unfit or unhealthy for watering stock. But it shall be the duty of every person, outside of incorporated towns, cities, or villages, to destroy all domestic refuse and garbage by burning the same; any violation of this section shall be considered a misdemeanor and punished as provided by law.

SEC. 2. All acts and parts of acts in conflict herewith are hereby repealed; and this act shall take effect from and after its passage.

[Laws of 1903, chap. 21, p. 32.]

AN ACT to prevent injury to ditches, pipe lines, reservoirs, and the taking of and befouling of water therefrom. (Approved March 10th, 1903.)

Be it enacted by the legislative assembly of the Territory of New Mexico:

SECTION 1. Any person who shall wilfully and maliciously cut, break, or injure, or who shall by shooting or by damming or obstructing the same cause to break any ditch, flume, pipe line, or reservoir, or any of the attachments or fixtures used in connection therewith, shall be guilty of a misdemeanor and shall be punished by a fine of not less than ten dollars nor more than fifty dollars, or by confinement in the county jail for not more than sixty days, or by both such fine and imprisonment, in the discretion of the court trying the case, except in cases where such pipe line or reservoir is used for the purpose of supplying water to any community, village, town, or city for domestic purposes, in which event the person committing such offence shall be punished by a fine of not less than fifty nor more than one hundred dollars, or by imprisonment in the county jail not less than thirty nor more than sixty days, or by both such fine and imprisonment in the discretion of the court trying the case.

SEC. 2. Any person who shall bathe in, or wilfully cast any filth in, any reservoir or ditch used for supplying water for domestic use shall be guilty of a misdemeanor, and upon conviction shall be fined not less than ten dollars or not more than twenty-five dollars.

SEC. 3. All acts and parts of acts in conflict herewith are hereby repealed, and this act shall take effect from and after its passage.

NORTH CAROLINA.

[North Carolina Criminal Code and Digest (2d ed.), p. 436.]

SEC. 500. Putting poisonous substance in water for the purpose of killing fish is forbidden.

Laws of 1903, chapter 245, page 321, forbids throwing sawdust into the water courses of Yancey County.

[Laws of North Carolina, 1903, chap. 159, p. 182.]

AN ACT to protect water supplies.

Sections 1 to 10, inclusive, provide a thorough system of inspection and forbid any person or corporation to supply water for the public without taking the precautions therein prescribed.

Sections 11 to 17 are as follows:

SEC. 11. Whoever defiles, corrupts, pollutes any well, spring, drain, branch, brook, or creek, or other source of public water supply used for drinking purposes, in any manner, or deposits the body of any dead animal on the watershed of any such water supply, or allows the same to remain thereon unless the same is buried with at least two feet cover, shall be guilty of a misdemeanor, and fined and imprisoned, in the discretion of the court.

SEC. 12. Whoever shall collect and deposit human excreta on the watershed of any public water supply shall be guilty of a misdemeanor, and punished by fine and imprisonment, in the discretion of the court.

SEC. 13. No person, firm, corporation, or municipality shall flow or discharge sewage into any drain, brook, creek, or river from which a public drinking-water supply is taken, unless the same shall have been passed through some well-known system of sewage purification approved by the State board of health. Any person, firm, corporation, or the officer of any municipality having this work in charge, who shall violate this section shall be guilty of a misdemeanor, and the continued flow and discharge of such sewage may be enjoined by any person.

SEC. 14. That all schools, hamlets, villages, towns, or industrial settlements which are now located or may be hereafter located on the shed of any public water supply not provided with a sewerage system, shall provide and maintain a tub system for collecting human excrement, and provide for removal of the same from the watershed at least twice each week. Every person, firm, corporation, or municipality violating this section shall be guilty of a misdemeanor, and fined or imprisoned, in the discretion of the court.

SEC. 15. No burying ground or cemetery shall be established on the watershed of any public water supply nearer than five hundred yards of the source of supply.

SEC. 16. All water companies now operating under charters from the State or municipalities, which may maintain public water supplies, may acquire by condemnation such lands and rights in land and water as are necessary for the successful operation and protection of their plants, said proceedings to be the same as prescribed by chapter 49, volume 1, of the Code of North Carolina.

SEC. 17. For carrying out the provisions of this act the State board of health is authorized and empowered to have the bacteriological examination made as hereinbefore provided for, and to charge for the same the sum of five dollars ($5.00) for each examination.

[Laws of 1905, chap. 415.]

AN ACT to establish a State laboratory of hygiene.

SECTION 1. That for the better protection of the public health and to prevent the spread of communicable diseases there shall be established a State laboratory of hygiene, the same to be under the control and management of the State board of health.

SEC. 2. That it shall be the duty of the State board of health to have made in such laboratory monthly examinations of samples from all the public water supplies of the State. The board shall also cause to be made examinations of well and spring waters when in the opinion of any county superintendent of health or any registered physician there is reason to suspect such waters of being contaminated and dangerous to health. The board shall likewise have made in this laboratory examinations of sputum in cases of suspected tuberculosis, of throat exudates in cases of suspected diphtheria, of blood in cases of suspected typhoid and malarial fever, of *fæces* in cases of suspected hook-worm diseases, and such other examinations as the public health may require.

SEC. 3. For the support of the said laboratory the sum of twelve hundred dollars is hereby appropriated and an annual tax of sixty dollars, payable quarterly, by each and every water company, municipal, corporate, and private, selling water to the people, said tax to be collected by the sheriff as other taxes and paid by said sheriff directly to the treasurer of the State board of health, and the printing and stationery necessary for the laboratory to be furnished upon requisition upon the State printer.

SEC. 4. Section seventeen of chapter one hundred and fifty-nine of the laws of one thousand nine hundred and three is hereby repealed.

SEC. 5. This act shall be in force from and after its ratification.

In the general assembly read three times, and ratified this 4th day of March, 1905.

OHIO.

[Bates's Annotated Revised Statutes of Ohio, p. 3343.]

SEC. 6921. *Nuisance.*—Whoever * * * corrupts or renders unwholesome or impure any water course, stream, or water * * * shall be fined not more than five hundred dollars.

SEC. 6923. (*Unlawful deposit of dead animals, offal, &c., into or upon land or water.*)—Whoever puts the carcass of any dead animal, or the offal from any slaughterhouse or butcher's establishment, packing house, or fish house, or any spoiled meat or spoiled fish, or any putrid substance, or the contents of any privy vaults, upon or into any lake, river, bay, creek, pond, canal, road, street, alley, lot, field, meadow, public ground, market place or common, and whoever, being the owner or occupant of any such place, knowingly permits any such thing to remain therein, to the annoyance of any of the citizens of this State, neglects or refuses to remove or abate the nuisance occasioned thereby, within twenty-four hours after knowledge of the existence of such nuisance upon any of the above-described premises, owned or occupied by him, or after notice thereof in writing from any supervisor, constable, trustee, or health officer of any municipal corporation or township in which such nuisance exists, or from a county commissioner of such county, shall be fined not more than fifty dollars nor less than ten dollars and pay the costs of prosecution, and in default of the payment of said fine and costs be imprisoned not more than thirty days; but the provisions hereinbefore made shall not prohibit the depositing of the contents of privy vaults and catch-basins into trenches or pits not less than three feet deep, excavated in any lot, field, or meadow, the owner thereof consenting, outside the limits of any municipal corporations, and not less than thirty rods distant from any dwelling, well, or spring of water, lake, bay, or pond, canal, run, creek, brook, or stream of water, public road or highway: *Provided*, That said contents deposited in said trenches or pits are immediately thereafter covered with dry earth to the depth of at least twelve inches; nor shall said provisions prohibit the depositing of said contents into furrows situate and distinct, as specified for said trenches or pits, provided the same are immediately thereafter wholly covered with dry earth by plowing or otherwise: *And provided also*, That the owner or occupant of the land in which said furrows are plowed consents and is a party thereto: *Provided also*, That the board of health of any municipal corporation may allow said contents to be deposited within corporate limits into trenches or pits or furrows, situate distant and to be covered as aforesaid.

SEC. 6925. *Emptying of coal dirt, petroleum, &c., into lakes, rivers, &c., or permitting same; penalty.*—Whoever intentionally throws or

deposits, or permits to be thrown or deposited, any coal dirt, coal slack, coal screenings, or coal refuse from coal mines, or any refuse or filth from any coal-oil refinery or gas works, or any whey or filthy drainage from a cheese factory, upon or into any of the rivers, lakes, ponds, or streams of this State, or upon or into any place from which the same will wash into any such river, lake, pond, or stream; or whoever shall, by himself, agent, or employe, cause, suffer, or permit any petroleum, or crude oil, or refined oil, or any compound or mixture or other product of such well, except fresh or salt water, or residuum of oil or filth from oil well, or oil tank, or oil vat, or place of deposit, of crude or refined oil, to run into, or be poured, or emptied, or thrown into any river, or ditch, or drain, or water course, or into any place from which said petroleum, or crude oil, or residuum, or refined oil, or filth may run or wash, or does run or wash, into any such river, or ditch, or drain, or water course, upon indictment and conviction in the county in which such coal mines, coal-oil refinery, gas works, cheese factory, oil well, oil tank, oil vat, or place of deposit of crude or refined oil are situated, shall be fined in any sum not more than one thousand dollars nor less than fifty dollars.

(*Fine and costs a lien; execution.*)—And such fine and costs of prosecution shall be and remain a lien on said oil well, oil tank, oil refinery, oil vat, and place of deposit, and the contents of said oil well, oil tank, oil refinery, oil vat, or place of deposit until said fine and costs are paid; and said oil well, oil tank, oil refinery, oil vat, or place of deposit, and the contents thereof, may be sold for the payment of such fine and costs upon execution duly issued for that purpose.

SEC. 6927. (*Befouling well, spring, &c.*)—Whoever maliciously puts any dead animal carcass, or part thereof, or any other putrid, nauseous, noisome, or offensive substance into, or in any manner befouls, any well, spring, brook, or branch of running water, or any reservoir of waterworks, of which use is or may be made for domestic purposes, shall be fined not more than fifty nor less than five dollars, or imprisoned not more than sixty days, or both.

[Laws of 1904, house bill 277, p. 135.]

AN ACT to amend section 2433, Revised Statutes of Ohio, for the purpose of preventing the pollution of water and providing penalty therefor.

SEC. 1. That section 2433, Revised Statutes of Ohio, be, and the same is hereby, amended to read as follows:

"SEC. 2433. The jurisdiction of any municipal corporation to prevent the pollution of its water supply and to provide penalty therefor shall extend twenty miles beyond the corporation limits. Whoever pollutes any running stream, the water of which is used for domesti purposes by any municipality by putting therein any putrid or offe

sive substance (other than fresh or salt water) injurious to health shall be guilty of a misdemeanor, which shall be punishable by a fine of not less than five or more than five hundred dollars. It shall be the duty of the board of public service or board of trustees of public affairs of any municipal corporation to enforce the provisions of this section."

SEC. 2. Original section 2433 is hereby repealed.

OREGON.

[Bellinger and Colton's Annotated Codes and Statutes of Oregon, vol. 1, p. 735.]

OF CRIMES AGAINST THE PUBLIC HEALTH.

SEC. 2128. *Polluting with sewage, &c., water for domestic use unlawful.*—Any person who shall put any sewage, drainage, or refuse, or polluting matter, as either by itself or in connection with other matter will corrupt or impair the quality of any well, spring, brook, creek, branch, or pond of water which is used or may be used for domestic purposes, shall be deemed guilty of misdemeanor. (Laws 1885, p. 110, sec. 1.)

SEC. 2129. *Animal carcass, &c., unlawful to place in water for domestic use or near dwelling.*—If any person shall put any dead animal carcass, or part thereof, excrement, putrid, nauseous, noisome, decaying, deleterious, or offensive substance into, or in any other manner not herein named befouls, pollutes, or impairs the quality of any spring, brook, creek, branch, well, or pond of water, which is or may be used for domestic purposes, or shall put any such dead animal carcass, or part thereof, excrement, putrid, nauseous, noisome, decaying, deleterious, or offensive substance within one-half mile of any dwelling house or public highway, and leave the same without proper burial, or, being in the possession or control of any land, shall knowingly permit or suffer any such dead animal carcass, or part thereof, excrement, putrid, nauseous, noisome, decaying, deleterious, or offensive substance to remain without proper burial upon such premises, within one-half mile of any dwelling house or public highway, whereby the same becomes offensive to the occupants of such dwelling or the traveling public, he shall be deemed guilty of a misdemeanor. (1885, p. 110, sec. 2.)

SEC. 2130. *Penalty for violating preceding provisions and jurisdiction to enforce.*—Any person violating the provisions of this act shall, upon conviction, be fined not less than ten nor more than fifty dollars, or be imprisoned not less than five days nor more than twenty-five days, or by both fine and imprisonment. Justices of the peace shall have jurisdiction of offences committed against the provisions of this act.

SEC. 2131. *Polluting water used for domestic purposes, or to which live stock have access, unlawful.*—If any person or persons shall put any dead animal's carcass, or part thereof, or any excrement, putrid, nauseous, decaying, deleterious, or offensive substance in any well, or into any spring, brook, or branch of running water, of which use is made for domestic purposes, or to which any cattle, horses, or other kind of stock have access, every person so offending shall, on conviction thereof, be fined in any sum not less than three nor more than fifty dollars.

SEC. 2133. *Animal carcass, unlawful to put in river or elsewhere to injury of health.*—If any person or persons shall put any part of the carcass of any dead animal into any river, creek, pond, road, street, alley, lane, lot, field, meadow, or common, or if the owner or owners thereof shall knowingly permit the same to remain in any of the aforesaid places to the injury of the health or to the annoyance of the citizens of this State, or any of them, every person so offending shall, on conviction thereof, be fined in a sum not less than two nor more than twenty-five dollars, and every twenty-four hours during which said owner may permit the same to remain thereafter shall be deemed an additional offence against the provisions of this act.

SOUTH DAKOTA.

[Revised Codes of 1903, Penal Code, p. 1146.]

SEC. 445. Every person who throws or deposits any gas tar, or refuse of any gas house or factory into any public waters, river, or stream, or into any sewer or stream emptying into such public waters, river, or stream, is guilty of a misdemeanor.

SEC. 446. It shall be unlawful for any person, persons, company, or corporation to place or cause to be placed any manure, butcher's offal, carcasses of animals, or other deleterious substances into any river, stream, or lake, in the State of South Dakota, or upon the banks thereof in such proximity that such substances may be washed into said water or water courses.

SEC. 447. Any violation of the provisions of this chapter is a misdemeanor, and the person, persons, company, or corporation so violating are deemed guilty thereof, and upon conviction shall be liable to a fine not less than ten dollars nor more than one hundred dollars, and in addition thereto such offending person or persons shall be subjected to imprisonment in the county jail for the period of thirty days unless he or they cause such deleterious substances to be removed.

SEC. 448. This act shall not be construed as to interfere with or prevent any necessary or legitimate mining operation or sewerage system.

TENNESSEE.

[Code of Tennessee, 1896.]

SEC. 6869. It is a public nuisance— * * *

3. To corrupt or render unwholesome or impure the water of any river, stream, or pond to the injury or prejudice of others.

SEC. 6520. If any person place or throw the dead body of any animal in any spring, well, cistern, or running stream of water he is guilty of a misdemeanor.

[1903, chap. 310, p. 905.]

Section 1 makes it a misdemeanor for "any person to in any way wilfully * * * disturb, pollute, contaminate, or injure the water in the tanks, standpipes, or reservoirs of any such waterworks by bathing therein or by any other act or acts tending to injure the water or to make it unpalatable, unwholesome, or unfit for domestic or manufacturing purposes of any plant supplying water for domestic or manufacturing purposes, however owned."

SEC. 2. That it shall be a misdemeanor for any person to wilfully corrupt or to permit anything to run or fall into any stream from which water shall be taken for the purpose of supplying water to any water plant such as is referred to in section 1 of this act, and any person violating this section shall be punished as provided in section 1 hereof.

Act takes effect April 7, 1903, on its passage.

TEXAS.

[White's Annotated Penal Code of Texas, p. 256.]

OFFENCES AFFECTING PUBLIC HEALTH.

ART. 424. If any person shall in any wise pollute of [a] [or?] obstruct any water course, lake, pond, marsh, or common sewer, or continue such obstruction or pollution so as to render the same unwholesome or offensive to the inhabitants of the county, city, town, or neighborhood thereabout, he shall be fined in a sum not exceeding five hundred dollars.

OFFENCES AGAINST THE PERSON.

ART. 647. If any person shall mingle or cause to be mingled any other noxious potion or substance with any drink, food, or medicine, with intent to kill or injure any other person, or shall wilfully poison or cause to be poisoned any spring, well, cistern, or reservoir of water with such intent, he shall be punished by imprisonment in the penitentiary not less than two nor more than ten years.

[a] So in original.

UTAH.

[Revised Statutes, p. 910, Penal Code: Public Health and Safety.]

SEC. 4274. *Befouling waters.*—Any person who shall either:

1. Construct or maintain any corral, sheep pen, stable, pigpen, chicken coop, or other offensive yard or outhouse, where the waste or drainage therefrom shall flow directly into the waters of any stream, well, or spring of water used for domestic purposes; or

2. Deposit, pile, unload, or leave any manure heap, offensive rubbish, or the carcass of any dead animal where the waste or drainage therefrom will flow directly into the waters of any stream, well, or spring of water used for domestic purposes; or

3. Dip or wash sheep in any stream, or construct, maintain, or use any pool or dipping vat for dipping or washing sheep in such close proximity to any stream used by the inhabitants of any city, town, or village for domestic pusposes as to make the waters thereof impure or unwholesome; or

4. Construct or maintain any corral, yard, or vat to be used for the purpose of shearing or dipping sheep within twelve miles of any city, town, or village, where the refuse or filth from said corral or yard would naturally find its way into any stream of water used by the inhabitants of any city, village, or town for domestic purposes; or

5. Establish and maintain any corral, camp, or bedding place for the purpose of herding, holding, or keeping any cattle, horses, sheep, or hogs within seven miles of any city, town, or village, where the refuse or filth from said corral, camp, or bedding place will naturally find its way into any stream of water used by the inhabitants of any city, town, or village for domestic purposes, shall be guilty of a misdemeanor.

[Laws of 1899, chap. 45, p. 66.]

SEC. 2. No house refuse, offal, garbage, dead animals, decaying vegetable matter, or organic waste substance of any kind shall be thrown on or allowed to remain upon any street, road, ditch, gutter, public place, private premises, vacant lot, water course, lake, pond, spring, or well.

VIRGINIA.

[Pollard's General Laws, 1887–1896, chap. 72, p. 44 (Acts 1887–88, p. 83).]

AN ACT to prevent the pollution of drinking water in this State. (Approved February 3, 1888.)

1. *Be it enacted by the general assembly of Virginia*, That any person or persons who shall knowingly and wilfully throw or cause to be thrown into any reservoir or other receptacle of drinking water,

or spring, or stream of running water ordinarily used for the supply of drinking water or domestic purposes of any person or family, town, or city in this Commonwealth the dead body of any animal, or shall drown and leave, or cause to be drowned and left any animal therein shall be guilty of a misdemeanor, and upon conviction thereof shall be fined not exceeding one hundred dollars or imprisoned not exceeding six months, or both, at the discretion of the court in which such conviction is made.

[Idem, p. 115 (Acts 1891-92, p. 759).]

AN ACT to prevent the pollution of potable water used for the supply of cities and towns. (Approved February 29, 1892.)

1. *Be it enacted by the general assembly of Virginia*, That it shall be unlawful, except as hereinafter provided, for any person to defile or render impure, turbid, or offensive the water used for the supply of any city or town of this State, or the sources or streams used for furnishing such supply, or to endanger the purity thereof by the following means, or any of them, to wit, by washing or bathing therein, or by casting into any spring, well, pond, lake, or reservoir from which such supply is drawn, or into any stream so used, or the tributary thereof above the point where such supply is taken out of such stream or is impounded for the purposes of such supply, or into any canal, aqueduct, or other channel or receptacle for water connected with any works for furnishing a public water supply, any offal, dead fish, or carcass of any animal, or any human or animal filth or other foul or waste animal matter, or any waste vegetable or mineral substance, or the refuse of any mine, manufactory, or manufacturing process, or by discharging or permitting to flow into any such source, spring, well, reservoir, pond, stream, or the tributary thereof, canal, aqueduct, or other receptacle for water, the contents of any sewer, privy, stable, or barnyard, or the impure drainage of any mine, any crude or refined petroleum, chemicals, or any foul, noxious, or offensive drainage whatsoever, or by constructing or maintaining any privy vault or cesspool, or by storing manure or other soluble fertilizer of an offensive character, or by disposing of the carcass of any animal, or any foul, noxious, or putrescible substance, whether solid or fluid and whether the same be buried or not, within two hundred feet of any water course, canal, pond, or lake aforesaid, which is liable to contamination by the washing thereof or percolation therefrom: *Provided*, That nothing in this act contained shall be construed to authorize the pollution of any of the waters of this State in any manner now contrary to law: *And provided further*, That this act shall not apply to streams the drainage area of which, above the point where the water thereof is withdrawn for the supply of any city or

town, or is impounded for the purposes of such supply, shall exceed fifty square miles.

2. That any person knowingly or wilfully violating the terms of this act shall be deemed guilty of a misdemeanor, and shall be punished for each offence by a fine not exceeding one hundred dollars or by imprisonment not exceeding thirty days, or by both, at the discretion of the court: *And provided further*, That nothing herein contained shall be so construed as to prevent the washing of ore or minerals in any of the streams or waters of this Commonwealth other than such as may be used for the water supply of any city or town.

3. This act shall take effect fifteen days after its passage.

WASHINGTON.

[Ballinger's Annotated Codes and Statutes, including acts of 1897.]

NUISANCES. Sec. 3085. It is a public nuisance:

* * * * * * *

2. To throw or deposit any offal or other offensive matter, or the carcass of any dead animal, in any water course, stream, lake, pond, spring, well, or common sewer, street or public highway, or in any manner to corrupt or render unwholesome or impure the water of any such spring, stream, pond, lake, or well, to the injury or prejudice of others.

Punishment provided in section 3097.

[Acts of 1899, Chap. LXX, p. 114: Providing for a pure water supply.]

AN ACT to preserve from pollution the water supplied to the inhabitants of cities and towns in the State of Washington; to declare what are nuisances in the vicinity of the source of such water supply; providing for the abatement thereof, and for the punishment of the violations of this act.

Be it enacted by the legislature of the State of Washington:

SECTION 1. That for the purpose of protecting the water furnished to the inhabitants of towns and cities within this State from pollution, the said towns and cities are hereby given jurisdiction over all property occupied by the works, reservoirs, systems, springs, branches, and pipes by means of which, and of all sources of supply from which, such cities or the companies or individuals furnishing water to the inhabitants of such cities or towns obtain their supply of water or store or conduct the same.

SEC. 2. That the establishment or maintenance of any slaughter pen, stock-feeding yards, hogpens, or the deposit or maintenance of any uncleanly or unwholesome substance, or the conduct of any business or occupation, or the allowing of any condition upon or sufficiently near the sources from which the supply of water for the

inhabitants of any such city or town is obtained, or where such water is stored, or the property or means through which the same may be conducted or conveyed, so that such water would be polluted or the purity of such water or any part thereof destroyed or endangered, is hereby prohibited and declared to be unlawful, and is hereby declared to be and constitute a nuisance, and as such to be abated as other nuisances are abated under the provisions of the existing laws of the State of Washington, or under the laws which may be hereafter enacted in relation to the abatement thereof; and that any person or persons who shall do, establish, maintain, or create any of the things hereby prohibited for the purpose of or which shall have the effect of polluting any such sources of water supply or water, or shall do any of the things hereby declared to be unlawful, shall be deemed guilty of creating and maintaining a nuisance, and may be prosecuted therefor, and upon conviction thereof may be fined in any sum not exceeding five hundred dollars.

SEC. 3. If upon the trial of any person or persons for the violation of any of the provisions of this act such person or persons shall be found guilty of creating or maintaining a nuisance as hereby defined or of violating any of the provisions of this act, it shall be the duty of such person or persons to forthwith abate such nuisance, and in the event of their failure so to do within one day after such conviction, unless further time be granted by the court, a warrant shall be issued by the court wherein such conviction was obtained directed to the sheriff of the county in which such nuisance exists, and the sheriff shall forthwith proceed to abate the said nuisance, and the cost thereof shall be taxed against the party so convicted as a part of the costs of such case.

SEC. 4. It is hereby made the duty of the city health officer, city physician, board of public health, mayor of the city, or such other officer as may have the sanitary condition of such city or town in charge, to see that the provisions of this act are enforced, and, upon complaint being made to any such officer, to immediately investigate the said complaint and see if the same shall appear to be well founded; and if the same shall appear to be well founded, it shall be, and is hereby, declared to be the duty of such officer to proceed and file a complaint against the person or persons violating any of the provisions of this act and cause the arrest and prosecution of such person or persons.

SEC. 5. That any city supplied with water from any source of supply as hereinbefore mentioned, or any corporation owning waterworks for the purpose of supplying any city or the inhabitants thereof with water, in the event that any of the provisions of this act are being violated by any person, may, by civil action in the superior

court of the proper county, have the maintenance of the nuisance which pollutes or tends to pollute the said water, as provided for by section 2 of this act, enjoined, and such injunction may be perpetual.

WEST VIRGINIA.

[Code of West Virginia, 1891, p. 933.]

OFFENCES AGAINST PUBLIC HEALTH—MISDEMEANOR TO PUT DEAD ANIMALS, ETC., INTO WATER USED FOR DOMESTIC PURPOSES.

If any person or persons shall knowingly and willfully throw or cause to be thrown into any well, cistern, spring, brook, or branch of running water which is used for domestic purposes, any dead animal, carcass, or part thereof, or any putrid, nauseous, or offensive substance, he or they shall be guilty of a misdemeanor, and upon conviction thereof shall be fined not less than five dollars nor more than one hundred dollars, and may, at the discretion of the jury, be confined in the jail of the county not exceeding ninety days, and shall moreover be liable to the party injured in a civil action for damages. (Acts 1872–73, ch. 176.)

PREVENTING THE DEPOSIT OF THE CARCASSES OF DEAD ANIMALS AND OTHER NOXIOUS MATTER IN CERTAIN WATERS OF THE STATE, ETC.

It shall be unlawful to put the carcass of any dead animal, or the offal from any slaughterhouse, butcher's establishment, or packing house, or slop or other refuse from any hotel or a tavern, or any spoiled meats or spoiled fish, or any putrid animal substance, or the contents of any privy vault, upon or into any river, creek, or other stream within this State, or upon the surface of any road, street, alley, city lot, public ground, market space, or common, or on the surface within one hundred feet of any public road.

III. A justice of the peace shall have jurisdiction of any offence against the provisions of this act, committed within his county. Any such offence shall be punished by a fine of not less than five or more than fifty dollars, and the proceedings in the case, as well as in all other cases under this act, shall be in conformity with sections 221 to 230, inclusive, or chapter 50 of the Code of West Virginia, which sections are hereby made applicable to such cases. Upon a conviction for any such offence the accused must bury at least three feet under the ground, or destroy by fire, any of the things named in the first section which he has placed in any of the waters or places named in such section, or which he has knowingly permitted to remain upon a city lot, public ground, market space, or common, contrary to the provisions of the second section, within twenty-four hours after such conviction, and if he shall fail to do so, the justice shall further fine him not less than ten nor more than fifty dollars. (Acts 1887, ch. 25.)

WYOMING.

[Revised Statutes, 1899.]

CRIMES AGAINST THE PERSON.

SEC. 4966. *Poisoning springs.*—Whoever poisons any spring, well, istern, or reservoir of water with intent to injure or kill any human eing shall be imprisoned in the penitentiary not more than fourteen ears.

CRIMES AGAINST PUBLIC HEALTH AND SAFETY.

SEC. 5114. *Putting offensive substances in creek or highway declared nuisance.*—If any person or persons, association of persons, company, or corporation shall deposit, place, or put, or cause to be deposited, placed, or put upon or into any river, creek, bay, pond, canal, litch, lake, stream, railroad, public or private road, highway, street, lley, lot, field, meadow, public place or public ground, common, narket place, or in any other and different locality in this State, where the same may become a source of annoyance to any person or letrimental to the public health, the carcass of any dead animal or he offal or refuse matter from any slaughterhouse, butcher's establishment, meat market, packing house, fish house, hogpen, stable, or ny spoiled meats, spoiled fish, or any animal or vegetable matter in a putrid or decayed state, or liable to become putrid, decayed, or offensive, or the contents of any privy vault, or any offensive matter or substance whatever, or shall cause to be maintained any privy, slaughterhouse, meat market, or any other or different place, building, or establishment that shall directly or indirectly be the cause of polluting the waters of any spring, reservoir, stream, lake, or water supply used wholly or partly for domestic purposes, or if the owner or owners, tenant or tenants, occupant or occupants of any lands or tenements, dwellings, or places of business, or any other and different places or localities, whether defined in this section or not, shall knowingly permit any of the said offensive matters or substances, or any other and different offensive matter or substances, to remain in any of the aforesaid places or other and different places or localities, or shall permit any of the aforesaid places to be maintained which shall cause the pollution of any stream, spring, reservoir, lake, or water supply, either directly or indirectly, in any locality, place, or situation in this State, to the annoyance of the citizens or residents of this State, or any of them, or to the detriment of the public health, or who shall neglect or refuse to remove or abate the nuisance, offence, or inconvenience occasioned or caused thereby within twenty-four hours after knowledge of the existence of such nuisance, offence, or inconvenience in or upon any of the above-described premises or places,

or any other and different place or locality, owned or occupied by him her, it, or they,[a] [them?] or after notice in writing from the sheriff, deputy sheriff, or coroner of any county in this State, or the constable of any precinct, or the marshal or any of the policemen of any city, town, or village in which such nuisance shall exist, or from any peace officer in this State of the locality wherein such nuisance shall exist, every such person so offending shall be guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine of not less than ten dollars nor more than fifty dollars, and if such nuisance is not abated within forty-eight hours after the same is created or exists to the knowledge of such offender, or within forty-eight hours after said written notice is given, such failure to abate such nuisance shall be deemed a second offence against the provisions of this section, and every like failure and neglect to abate such nuisance of each twenty-four hours thereafter shall be considered an additional offence, and shall be subject to a like penalty as is herein provided.

SEC. 5115. *Abatement of nuisance.*—Provides that officer shall remove nuisance, on neglect of owners so to do, expenses collectible in civil action.

SEC. 5116. *Throwing sawdust into streams.*—If any person or persons who may own, run, or have charge of any sawmill in this State shall throw or permit the sawdust therefrom to be thrown or placed in any manner into any river, stream, creek, bay, pond, lake, canal, ditch, or other water course in this State, such person or persons shall be liable to a like penalty as is provided in section 5114.

[Laws of Wyoming, 1905, chap. 31, p. 25.]

FISH—POLLUTING WATERS.

AN ACT To repeal section 1 of chapter 22 of the session laws of Wyoming of the year A. D. 1903, being an act entitled "An act to amend and reenact section 2146, revised statutes of Wyoming, 1899, relating to the unlawful taking or having in possession of certain kinds of fish," and to amend and reenact section 2148, revised statutes of Wyoming, 1899, relating to the unlawful placing of deleterious substances, poisons, or explosives in the waters of the State.

SEC. 1. That section 1, chapter 22, of the session laws of Wyoming, 1903, being "An act to amend and reenact section 2146 of the revised statutes of Wyoming, 1899, relating to the unlawful taking or having in possession of certain kinds of fish," be and the same is hereby repealed.

SEC. 2. That section 2148 of the revised statutes of Wyoming, 1899, be amended and reenacted so as to read as follows:

"SEC. 2148. Any owner or owners of any sawmill, reduction works, smelter, refining or contraction works, or any of the employees

[a] So in original.

thereof, who shall throw, deposit, or in any way permit to pass into any natural stream or lake wherein are living fish, any sawdust, chemicals, or other matter or substance that will tend to drive away from such waters any fish shall be deemed guilty of a misdemeanor and shall be fined not less than twenty-five dollars nor more than one hundred dollars, or shall be imprisoned in the county jail not less than thirty days nor more than sixty days. Any person who shall kill in any of the waters of this State, by use of any poison or deleterious drug, or by the use of any explosive substance, or explode or cause to be exploded any powder, giant powder, hercules powder, dynamite, nitroglycerine, lime gas, or any other explosive substance for the purpose of catching, killing, or destroying food fish in such waters shall be deemed guilty of a misdemeanor and upon conviction thereof shall be fined not less than fifty dollars nor more than two hundred dollars, and shall be imprisoned in the county jail not less than ninety days nor more than one year: *Provided further*, That nothing in this title contained shall prevent the owner or owners of any quartz mill or reduction works in this State, now located or to be hereafter located upon any natural stream or lake, from operating or working said quartz mill or reduction works, where the said owner or owners thereof shall build or cause to be built a suitable dam, to be used in connection with said quartz mill or reduction works, and which dam shall be so constructed as to prevent any tailings or substance from passing into the stream or lake which will destroy or drive away the fish or any number of them from said stream, lake, or water."

SEC. 3. This act shall take effect and be in force from and after its passage.

Approved February 15, A. D. 1905.

[Chapter 83, House bill No. 87.]

FISH.

AN ACT to repeal section 1 of chapter 22 of the session laws of Wyoming of the year A. D. 1903, being an act entitled "An act to amend and reenact section 2146, revised statutes of Wyoming, 1899, relating to the unlawful taking or having in possession of certain kinds of fish," and to amend and reenact section 2148, revised statutes of Wyoming, 1899, relating to the unlawful placing of deleterious substances, poisons, or explosives in the waters of the State.

SEC. 1. *Repeal of sec. 1, chap. 22, laws 1903.*—That section 1, chapter 22, of the session laws of Wyoming, 1903, being "An act to amend and reenact section 2146 of the revised statutes of Wyoming, 1899, relating to the unlawful taking or having in possession of certain kinds of fish" be, and the same is hereby, repealed.

SEC. 2. *Use of explosives and poison.*—That section 2148 of the revised statutes of Wyoming, 1899, be amended and reenacted so as to read as follows:

"SEC. 2148. Any owner or owners of any sawmill, or any of the employees thereof, who shall throw, deposit, or in any way permit to pass into any natural stream or lake wherein are living fish any sawdust or other matter or substance that will tend to drive away from such waters any fish, shall be deemed guilty of a misdemeanor, and shall be fined not less than twenty-five dollars nor more than one hundred dollars, or shall be imprisoned in the county jail not less than thirty days nor more than sixty days. Any person who shall kill in any of the waters of this State, by use of any poison or deleterious drug, or by use of any explosive substances, or explode or cause to be exploded any powder, giant powder, hercules powder, dynamite, nitroglycerine, lime gas, or any other explosive substance for the purpose of catching, killing, or destroying the food fish in such waters, shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be fined not less than fifty dollars nor more than two hundred dollars, and shall be imprisoned in the county jail not less than ninety days nor more than one year."

SEC. 3. This act shall take effect and be in force from and after its passage.

Approved February 21, A. D. 1905.

CLASS III. STATES WITH SEVERE RESTRICTIONS.

This group consists of those States which have adopted unusual and stringent methods to enforce the right of their citizens to unpolluted natural waters. The adoption of the legislation embodied in the following pages under this group indicates that the inhabitants of the States in which these laws have been adopted have begun to realize the immense harm which the increased pollution of waters, owing to increase of population, is doing to persons and property within their borders. It is noticeable that in several of the States stringent methods are adopted by which pollution by cities can be regulated and controlled; while in at least one State (New Jersey) a system has been instituted which, carried to its logical conclusion, will result in conveying all sewage matter from cities and large towns so far beyond the borders of the land as to render it wholly inoffensive or in some other way preventing its getting into any inland waters in an offensive form.

CONNECTICUT.

[General Statutes, revision of 1902, sec. 1328, as amended by chap. 28, of the laws of 1905.]

Every person who shall wantonly and indecently expose his person, r who shall bathe in any reservoir from which the inhabitants of ny town, city or borough are supplied with water, or in any lake, ond or stream tributary to such reservoir, or who shall cast any lthy or impure substance into said reservoir, or any of its tribuaries, or commit any nuisance in or about it or them, shall be fined ot more than one hundred dollars, or imprisoned not more than six ionths, or both.

[General Statutes, revision of 1902, p. 668.]

SEC. 2593. *Pollution of water from which ice is taken.*—Every perin who shall put any substance into waters from which ice is proired for consumption which shall defile, pollute, or injure the uality of said ice, or who shall throw anything into such waters or pon the ice with intent to injure the quality of the ice or obstruct ie cutting or gathering of the same, shall be fined not more than iirty dollars or imprisoned not more than thirty days. This section iall not affect the rights of any manufacturing establishment now xisting or hereafter established to use any waters in carrying on its business.

SEC. 2594. *Pollution of waters.*—Every person who shall put or leave a dead animal or carcass in a pond, spring, or reservoir, the water of which is conveyed to any building, or who shall wilfully put and leave in any of the waters of this State a dead animal, shall be fined not more than fifty dollars or imprisoned not more than thirty days.

SEC. 2595. *Penalty for polluting drinking water.*—Every person who shall put anything into a well, spring, fountain, or cistern, or other place from which water is procured for drinking or other purposes, with the intent to injure the quality of said water, shall be fined not more than five hundred dollars or imprisoned not more than six months.

SEC. 2596. *Analysis of water.*—Town, borough, and city health officers shall, when in their judgment health is menaced or impaired through a water supply, send, subject to the approval of the county health officer, samples of such water to the State board of health for examination and analysis, and the expense of such examination and analysis shall be paid out of the funds appropriated to said board to investigate the pollution of streams.

SEC. 2598. *Location of cemeteries.*—No cemetery or place of sepulture shall hereafter be located or established within one-half mile of

any reservoir from which the inhabitants of a town, city, or borough are supplied with water; nor shall such reservoir be located or established within one-half mile of a cemetery or place of sepulture unless the superior court of the county wherein such cemetery or place of sepulture or reservoir is located shall, upon application or notice find that such cemetery or place of sepulture or such reservoir so proposed to be located is of public convenience and necessity and will not be detrimental to the public health.

SEC. 2602. *Pollution of reservoirs—Penalty.*—No person, after notice shall have been posted that any reservoir, or any lake, pond, or stream tributary thereto, is used for supplying the inhabitants of a town, city, or borough with water, shall wash any animal, clothing, or other article therein. No person shall throw any noxious or harmful substance into such reservoir, lake, pond, or stream, nor shall any person, after receipt of written notice from any county or town health officer having jurisdiction that the same is detrimental to such water supply, suffer any such substance to be placed upon land owned, occupied, or controlled by him, so that the same may be carried by rains or freshets into the water of such reservoir, lake, pond, stream, or drain, or allow to be drained any sewage from said land into such water. Every person who shall violate any provision of this section shall be fined not more than one hundred dollars or imprisoned not more than thirty days, or both.

SEC. 2603. *Appointment of special police.*—The governor may, upon the application of such town, borough, city, or company, commission during his pleasure one or more persons who, having been sworn, may act as policemen for the purpose of preventing and abating nuisances and protecting such water supply from contamination. Such policemen shall arrest without previous complaint and warrant any person for any offense under the provisions of any law for the protection of water supplies when the offender shall be taken or apprehended in the act or on the speedy information of others, and all persons so arrested shall be immediately presented before proper authority. Every such policeman shall, when on duty, wear in plain view a shield bearing the words "Special police" and the name of the town, city, borough, or company for which he is commissioned.

[Acts of 1903, chap. 192, p. 148.]

AN ACT concerning injunctions.

Be it enacted by the senate and house of representatives in general assembly convened.

SECTION 1. Section 2599 of the General Statutes is hereby amended to read as follows: Whenever any land or building is so used, occupied or suffered to remain, that it is a source of injury to the wat

stored in a reservoir used for supplying a town, city, or borough with water, or to any source of supply to such reservoir, or when such water is liable to pollution in consequence of the use of the same, either the authorities of such town, city, or borough, or the company having charge of said water, may apply to the superior court, or any judge thereof in vacation, in the county in which said town, city, borough, or company is located, for relief; and said court or judge may order the removal of any building, enjoin any use or occupation of any land or building or of said water which is detrimental to said water, or make any other order, temporary or permanent, which in its or his judgment may be necessary to preserve the purity of said water. Said town, city, borough, or company may, by its officers or agents, duly appointed for such purpose, at all reasonable times enter upon and inspect any premises within the watershed tributary to such water supply, and in case any nuisance shall be found thereon which pollutes or is likely to pollute such water, may abate such nuisance at its own expense after reasonable notice to the owner or occupant of said premises and upon his neglect or refusal to abate the same; but such town, city, borough, or company shall be liable for all unnecessary or unreasonable damage done to said premises.

SEC. 2. Section 2600 of the General Statutes is hereby amended to read as follows: Any city, town, borough, or corporation authorized by law to supply the inhabitants of any city, town, or borough with pure water for public or domestic use may take and use such lands, springs, streams, or ponds, or such rights or interests therein as the superior court or any judge thereof in vacation may, on application, deem necessary for the purposes of such supply. For the purpose of preserving the purity of such water and preventing any contamination thereof, such city, town, borough, or corporation may take such lands or rights as the superior court or any judge thereof in vacation may, on application, deem necessary therefor. Compensation shall be made to all persons entitled thereto in the manner provided by section 2601.

SEC. 3. Section 2601 of the General Statutes is hereby amended to read as follows: In all cases where the law requires compensation to be made to any person whose rights, interests, or property are injuriously affected by said orders, such court or judge shall appoint a committee of three disinterested freeholders of the county who shall determine and award the amount to be paid by such authorities before such order is carried into effect.

Approved June 18, 1903.

MASSACHUSETTS.

[Revised laws of the Commonwealth of Massachusetts, enacted November 21, 1901, taking effect January 1, 1902, chap. 75, p. 677.]

OF THE PRESERVATION OF THE PUBLIC HEALTH.

SEC. 112. *Supervision of inland waters.*—The State board of health shall have the general oversight and care of all inland waters and of all streams and ponds used by any city, town, or public institution, or by any water or ice company, in this Commonwealth as sources of water supply, and of all springs, streams, and water courses tributary thereto. It shall be provided with maps, plans, and documents suitable for such purposes and shall keep records of all its transactions relative thereto.

SEC. 113. *Examination of water supply.*—Said board may cause examinations of such waters to be made to ascertain their purity and fitness for domestic use or their liability to impair the interests of the public or of persons lawfully using them or to impair the public health. It may make rules and regulations to prevent the pollution and to secure the sanitary protection of all such waters as are used as sources of water supply.

SEC. 114. *Effect of publication of notice.*—The publication of an order, rule, or regulation made by the board under the provisions of the preceding section, or section one hundred and eighteen, in a newspaper of the city or town in which such order, rule, or regulation is to take effect, or, if no newspaper is published in such city or town, the posting of a copy of such order, rule, or regulation in a public place in such city or town, shall be legal notice to all persons, and an affidavit of such publication or posting by the person causing such notice to be published or posted, filed and recorded with a copy of the notice in the office of the clerk of such city or town, shall be admitted as evidence of the time at which, and the place and manner in which, the notice was given.

SEC. 115. *Report and recommendations.*—Said board shall annually, on or before the tenth day of January, make a report to the general court of its doings for the preceding year, recommend measures for the prevention of the pollution of such waters and for the removal of polluting substances in order to protect and develop the rights and property of the Commonwealth therein and to protect the public health, and recommend any legislation or plans for systems of main sewers necessary for the preservation of the public health and for the purification and prevention of pollution of the ponds, streams, and inland waters of the Commonwealth. It shall also give notice to the attorney-general of any violation of law relative to the pollution of water supplies and inland waters.

SEC. 116. *Agents and assistants.*—Said board may appoint, employ, and fix the compensation of such agents, clerks, servants, engineers, and expert assistants as it considers necessary. Such agents and servants shall cause the provisions of law relative to the pollution of water supply and of the rules and regulations of said board to be enforced.

SEC. 117. *Advice as to methods.*—Said board shall consult with and advise the authorities of cities and towns and persons having, or about to have, systems of water supply, drainage, or sewerage as to the most appropriate source of water supply, and the best method of assuring its purity or as to the best method of disposing of their drainage or sewage with reference to the existing and future needs of other cities, towns, or persons which may be affected thereby. It shall also consult with and advise persons engaged or intending to engage in any manufacturing or other business whose drainage or sewage may tend to pollute any inland water as to the best method of preventing such pollution, and it may conduct experiments to determine the best methods of the purification or disposal of drainage or sewage. No person shall be required to bear the expense of such consultation, advice, or experiments. Cities, towns, and persons shall submit to said board, for its advice, their proposed system of water supply or of the disposal of drainage or sewage, and all petitions to the general court for authority to introduce a system of water supply, drainage, or sewerage shall be accompanied by a copy of the recommendation and advice of said board thereon. In this section the term "drainage" means rainfall, surface, and subsoil water only, and "sewage" means domestic and manufacturing filth and refuse.

SEC. 118. *Removal of causes of pollution.*—Upon petition to said board by the mayor of a city or the selectmen of a town, the managing board or officer of any public institution, or by a board of water commissioners, or the president of a water or ice company, stating that manure, excrement, garbage, sewage, or any other matter pollutes or tends to pollute the waters of any stream, pond, spring, or water course used by such city, town, institution, or company as a source of water supply, the board shall appoint a time and place within the county where the nuisance or pollution is alleged to exist for a hearing, and after notice thereof to parties interested and a hearing, if in its judgment the public health so requires, shall, by an order served upon the party causing or permitting such pollution, prohibit the deposit, keeping, or discharge of any such cause of pollution, and shall order him to desist therefrom and to remove any such cause of pollution; but the board shall not prohibit the cultivation and use of the soil in the ordinary methods of agriculture if no human excrement is used thereon. Said board shall not prohibit the

use of any structure which was in existence on the eleventh day of June, in the year eighteen hundred and ninety-seven, upon a complaint made by the board of water commissioners of any city or town or by any water or ice company, unless such board of water commissioners or company files with the State board a vote of its city council, selectmen, or company, respectively, that such city, town, or company will, at its own expense, make such changes in said structure or its location as said board shall deem expedient. Such vote shall be binding on such city, town, or company. All damages caused by such changes shall be paid by such city, town, or company; and if the parties can not agree thereon, the damages shall, on petition of either party, filed within one year after such changes are made, be assessed by a jury in the superior court for the county where the structure is located.

SEC. 119. *Appeal from order.*—Whoever is aggrieved by an order passed under the provisions of the preceding section may appeal therefrom in the manner provided in sections 95 and 97, but such notice as the court shall order shall also be given to the board of water commissioners and mayor of the city or chairmen of the selectmen of the town or president or other officer of the water or ice company interested in such order. While the appeal is pending the order of the board shall be complied with, unless otherwise authorized by the board.

SEC. 120. *Enforcement of law.*—The supreme judicial court or the superior court shall have jurisdiction in equity, upon the application of the State board of health or of any party interested, to enforce its orders or the orders, rules, and regulations of said board of health, and to restrain the use or occupation of the premises or such portion thereof as said board may specify, on which said material is deposited or kept, or such other cause of pollution exists, until the orders, rules, and regulations of said board have been complied with.

SEC. 121. *Entry on premises.*—The agents and servants of said board may enter any building, structure, or premises for the purpose of ascertaining whether sources of pollution or danger to the water supply there exist, and whether the rules, regulations, and orders aforesaid are obeyed. Their compensation for services rendered in connection with proceedings under the provisions of section 118 shall be fixed by the board and shall in the first instance be paid by the Commonwealth; but the whole amount so paid shall, at the end of each year, be justly and equitably apportioned by the tax commissioner between such cities, towns, or companies as, during said year, have instituted said proceedings, and may be recovered in an action by the treasurer and receiver-general, with interest from date of the demand.

SEC. 122. *Penalties.*—Whoever violates any rule, regulation, or order made under the provisions of section 113 or section 118 shall be punished for each offence by a fine of not more than five hundred dollars, to the use of the Commonwealth, or by imprisonment for not more than one year, or by both such fine and imprisonment.

SEC. 123. *Application of preceding sections.*—The provisions of the eleven preceding sections shall not apply to the Merrimac or Connecticut rivers, nor to so much of the Concord River as lies within the limits of the city of Lowell, nor to springs, streams, ponds, or water courses over which the metropolitan water board has control.

SEC. 124. *Sources of water supply—as to.*—The provisions of the refuse, or polluting matter of such kind and amount as either by itself or in connection with other matter will corrupt or impair the quality of the water of any pond or stream used as a source of ice or water supply by a city, town, public institution, or water company for domestic use, or render it injurious to health, and no human excrement shall be discharged into any such stream or pond, or upon their banks if any filter basin so used is there situated, or into any feeders of such pond or stream within twenty miles above the point where such supply is taken.

SEC. 125. *Prescriptive rights unaffected—application limited.*—The provisions of the preceding section shall not destroy or impair rights acquired by legislative grant prior to the first day of July in the year 1878, or destroy or impair prescriptive rights of drainage or discharge, to the extent to which they lawfully existed on that date; nor shall it be applicable to the Merrimac or Connecticut rivers, or to so much of the Concord River as lies within the limits of the city of Lowell.

SEC. 126. *Injunction against pollution of water supply.*—The supreme judicial court or the superior court, upon application of the mayor of a city, the selectmen of a town, managing board or officer of a public institution, or a water or ice company interested, shall have jurisdiction in equity to enjoin the violation of the provisions of sec. 124.

SEC. 127. *Penalty for corrupting spring, etc.*—Whoever willfully and maliciously defiles or corrupts any spring or other source of water, or reservoir, or destroys or injures any pipe, conductor of water, or other property pertaining to an aqueduct, or aids or abets in any such trespass, shall be punished by a fine of not more than one thousand dollars or by imprisonment for not more than one year.

SEC. 128. *Penalty for corrupting sources of water supply.*—Whoever willfully deposits excrement or foul or decaying matter in water which is used for the purpose of domestic water supply, or upon the shore thereof within five rods of the water, shall be punished by a

fine of not more than fifty dollars or by imprisonment for not more than thirty days; and a police officer or constable of a city or town in which such water is wholly or partly situated, acting within the limits of his city or town, and any executive officer or agent of a water board, board of water commissioners, public institution, or water company furnishing water or ice for domestic purposes, acting upon the premises of such board, institution, or company, and not more than five rods from the water, may, without a warrant, arrest any person found in the act of violating the provisions of this section and detain him until a complaint can be made against him therefor. But the provisions of this section shall not interfere with the sewage of a city, town, or public institution, or prevent the enriching of land for agricultural purposes by the owner or occupant thereof.

SEC. 129. *Penalty for bathing in public ponds.*—Whoever bathes in a pond, stream, or reservoir the water of which is used for the purpose of domestic water supply for a city or town, shall be punished by a fine of not more than ten dollars.

SEC. 130. *Penalty for driving on ice of pond used for water supply.*—Whoever, not being engaged in cutting or harvesting ice, or in hauling logs, wood, or lumber, drives any animal on the ice of a pond or stream which is used for the purpose of domestic water supply for a city or town, shall be punished by a fine of not more than fifty dollars or by imprisonment for not more than thirty days.

NOTE.—Sections 95 and 97, referred to in section 119, provide for an appeal to the superior court of the county and a jury trial. The verdict may alter, affirm, or annul the order, and shall be returned to the court for acceptance, and, if accepted, shall have the authority and effect of a valid order of the board.

MINNESOTA.

[General Statutes, p. 120.]

SEC. 430. *Pollution of sources of water supply forbidden.*—No sewage, drainage, or refuse, or polluting matter of such kind as, either by itself or in connection with other matter, will corrupt or impair the quality of the water of any spring, well, pond, lake, stream, or river for domestic use, or render it injurious to health, and no human or animal excrement shall be placed in or discharged into or placed or deposited upon the ice of any pond, lake, stream, or river used as a source of water supply by any town, village, or city; nor shall any such sewage, drainage, refuse, or polluting matter or excrement be placed upon the banks of any such pond, lake, stream, or river within five miles above the point where such supply is taken, or into any feeders or the banks thereof of any such pond, lake, stream, or river;

Provided, nothing in this section contained shall apply to Lake Superior. (1885. Chap. 225, sec. 1.)

SEC. 431. *Supervision of sources of water supply—procedure in cases of pollution.*—The State board of health shall have the general supervision of all springs, wells, ponds, lakes, streams, or rivers used by any town, village, or city as a source of water supply, with reference to their purity, together with the waters feeding the same, and shall examine the same from time to time, and inquire what, if any, pollution exists and their causes. In case of a violation of any of the provisions of section one of this act (sec. 430) said board may appoint a time and place for hearing parties to be affected, and shall give due notice thereof, as hereinafter provided, to such parties; and after such hearing, if in its judgment the public health requires it, may order any person or corporation, or municipal corporation, to desist from the acts causing such pollution, and may direct any such person or corporation to remedy the pollution, or to cleanse or purify the polluting substances in such a manner and to such a degree as shall be directed by said board, before being cast or allowed to flow into the waters thereby polluted, or placed or deposited upon the ice or banks of any of the bodies of water in the first section of this act mentioned. Upon the application of the proper officers of any town, village, or city, or of not less than ten legal voters of any such town, village, or city, to said State board, alleging the pollution of the water supply of any such town, village, or city by the violation of any of the provisions of this act, said State board shall investigate the alleged pollution, and shall appoint a time and place when and where it will hear and examine the matter, and shall give notice of such hearing and examination to the complainant, and also to the person or corporation or municipal corporation alleged to have caused such pollution, and such notice shall be served not less than ten days prior to the time so appointed, and shall be served in the same manner that now is or hereafter may be by law provided for the service of a summons in a civil action in the district court. Said board, if in its judgment any of the provisions of this act have been violated, shall issue the order or orders already mentioned in this section. (1885. Chap. 225, sec. 2.)

NEW HAMPSHIRE.

[Public statutes of New Hampshire and general laws in force Jan. 1, 1901, p. 337, chap. 108. (Wm. M. and Arthur H. Chase.)]

Section 13, entitled, "The prevention and removal of nuisances," is as follows: "If a person shall place, leave, or cause to be placed or left in or near a lake, pond, reservoir, or stream tributary thereto, from which the water supply for domestic purposes of a city, town, or village is taken, in whole or in part, any substance or fluid that may

cause the water thereof to become impure or unfit for such purposes, he shall be fined not exceeding twenty dollars or be imprisoned not exceeding thirty days, or both."

SEC. 14. The board of health of the town or the water commissioners having charge of the water supply or the proprietors thereof may remove such substance or fluid, and they may recover the expense of removal from the person who placed the same or caused it to be placed in or near the water as aforesaid in an action on the case.

[Laws of 1895, chap. 76, p. 433.]

AN ACT to protect waters used for domestic purposes.

Be it enacted by the senate and house of representatives in general court convened:

SECTION 1. Whoever knowingly and wilfully poisons, defiles, pollutes, or in any way corrupts the waters or ice of any well, spring, brook, lake, pond, river, or reservoir used as the source of a public water or ice supply for domestic purposes, or knowingly corrupts the sources of the water of any water company or of any city or town supplying its inhabitants with water, or the tributaries of said sources of supply, in such a manner as to affect the purity of the water or ice so supplied at the point where the water or ice is taken for such domestic use, or puts the carcass of any dead animal or other offensive material into said waters or upon the ice thereof, shall be punished by a fine not exceeding one thousand dollars or by imprisonment not exceeding one year. The provisions of this section shall not apply to the deposit of any bark, sawdust, or any other waste of any kind arising from the business of cutting, hauling, driving, or storing logs, or the manufacture of lumber; and the use of any stream for the purposes of manufacturing and for the necessary drainage connected therewith, if more than four miles distant from the point where the water is taken for such domestic purposes, shall not be deemed a violation of this section.

SEC. 2. No person shall cut or take ice from any lake, pond, or reservoir used as the source of a public water or ice supply for domestic purposes for man, unless he first shall comply in all respects with such reasonable rules and regulations in regard to the manner and place of cutting and taking such ice on said lake, pond, or reservoir as may be prescribed by the local board of control or officers of a water company who may have charge of the works of any city or town supplying its inhabitants with water from said lake, pond, or reservoir. The supreme court shall have power to issue injunctions restraining any person from cutting or taking ice from such lakes, ponds, or reservoirs until they have complied with the reasonable regulations made as aforesaid.

SEC. 3. Said local boards and officers may also make all reasonable rules and regulations in regard to fishing and the use of boats in and upon any such lake, pond, or reservoir, and in regard to racing or speeding horses upon the ice thereof, which they may deem expedient. Any person who shall violate any of said rules and regulations after notice thereof shall be fined not exceeding twenty dollars, or imprisoned not exceeding six months.

SEC. 4. If any person shall bathe in such lake, pond, or reservoir within one-fourth mile of the point where said water is taken, he shall be fined not exceeding twenty dollars, or imprisoned not exceeding six months.

SEC. 5. Whoever shall wilfully injure any of the property of any water company or of any city or town, used by it in supplying water to its inhabitants, shall be punished by a fine not exceeding one thousand dollars, or by imprisonment not exceeding one year; and such person shall also forfeit and pay to such water company, city, or town three times the amount of actual damages sustained, to be recovered in an action on the case.

SEC. 6. All acts and parts of acts inconsistent with this act are hereby repealed, but nothing in this act shall be construed to repeal any special act applying to cities and towns.

[Laws of 1897, chap. 85, p. 82.]

SECTION 1. It shall be the duty of boards of health of the cities and towns of the State to examine and inspect the sources from which ice is cut, or is proposed to be cut, for domestic use in such cities and towns, and to employ such means as may be necessary to determine whether the waters of such sources of ice supply have been polluted, or whether ice taken therefrom will be deleterious to the public health.

SEC. 2. In each case where the waters of the sources of ice supplies shall be found so polluted that the ice taken therefrom will be unhealthy or unsafe for domestic use, the board of health of the city or town concerned in the same shall immediately notify such person or persons as may have taken, or who propose to take ice from such polluted source for their own domestic use or for sale for domestic use, of the dangerous character of the waters inspected and that the taking of such ice for domestic use must cease.

SEC. 3. Whoever knowingly or wilfully shall cut or take any ice for domestic purposes from any waters which are polluted with sewage or other substance deleterious or dangerous to life or health, or from waters which a board of health has condemned, shall be fined not exceeding two hundred and fifty dollars or imprisoned not exceeding six months.

[Acts of 1899, chap. 57.]

SECTION 1. Whenever any board of water commissioners, local board of health, or ten or more citizens of any town or city have reason to believe that a public water or ice supply is being contaminated or is in danger of contamination, and that the local regulations are not sufficient or effective to prevent such pollution, they may petition the State board of health to investigate the case and to establish such regulations as the said board may deem necessary for the protection of the said supply against any pollution that in its judgment would endanger the public health.

SEC. 2. The State board of health shall, after due investigation, make such regulations as it may deem best to protect the said supply against any dangerous contamination, and the regulations so made shall be in force when a copy is filed with the town clerk and posted in two or more public places in said town, or published in some newspaper in the county, and it shall be the duty of the local board of health to enforce said regulations.

SEC. 3. Any person violating any regulation established by the State board of health shall be punished by a fine of twenty dollars for each offense, and a certified copy under oath of such regulation, made by the secretary of the State board of health or by the town clerk where the regulations are filed, shall be received as prima facie evidence of such regulations in any court of the State.

[Laws of 1905, chap. 12.]

AN ACT to protect the waters of Alton Bay from pollution by sawdust and other waste.

SEC. 1. That no sawdust, shavings, or other waste product of sawmills, planing mills, or other manufactories shall be deposited, dumped, or placed in that part of Lake Winnipesaukee known as Alton Bay, nor shall any sawdust, shavings, or other waste products be allowed to escape into, or be deposited, dumped, or placed in any stream which runs or empties into said bay.

SEC. 2. Any person, or any officer of any corporation, violating the provisions of this act shall be fined not exceeding twenty-five dollars for each offense, and each day of a violation of the same shall be deemed a separate offense.

SEC. 3. All acts and parts of acts inconsistent with this act are hereby repealed.

SEC. 4. This act shall take effect on April 1, 1905.

Approved February 9, 1905.

[Laws of 1905, chap. 73.]

AN ACT to prohibit the deposit of sawdust and other sawmill refuse and other waste in Swift River and its tributaries in the town of Tamworth.

SEC. 1. Any person who shall deposit, dump, place, or cause to be deposited, dumped, or placed any sawdust or other sawmill refuse, rubbish, or other waste in Swift River and its tributaries, in the town of Tamworth, shall be fined not less than ten dollars nor more than fifty dollars.

SEC. 2. This act shall take effect upon its passage.

Approved March 9, 1905.

[Laws of 1905, chap. 74.]

AN ACT to protect Mink Brook from pollution by sawdust and other waste.

SEC. 1. No person or corporation shall put or place, or cause or allow to be put or placed, any sawdust, shavings, edgings, chips, bark, or other waste from woodwork establishments into Mink Brook in the town of Hanover.

SEC. 2. Any person or corporation violating the provisions of this act shall be punished by a fine not exceeding ten dollars for each offense, and every day that they violate the same shall be deemed a separate offense.

SEC. 3. This act shall take effect June 1, 1905.

Approved March 9, 1905.

[Laws of 1905, chap. 88.]

AN ACT to protect Union River and its tributaries from pollution by sawdust and other waste.

SEC. 1. No person or corporation shall put or place, or cause to be put or placed, any sawdust, shavings, edgings, chips, bark, or other waste from sawmills or other woodwork establishments into Union River, so called, or its tributaries, in the towns of Brookfield and Wakefield in Carroll County, and the town of Milton in Strafford County. Any person or corporation violating the provisions of this act shall be punished by a fine not exceeding one hundred dollars for each offense.

SEC. 2. This act shall take effect on April 15, 1905.

Approved March 10, 1905.

NEW JERSEY.

[General Statutes, p. 1109.]

AN ACT to prevent the pollution of the waters of any of the creeks, ponds, or brooks of this State. (Approved March 29, 1878.)

322. SECTION 1. That if any person or persons shall throw, cause or permit to be thrown, into the waters of any creek, pond, or brook of

this State, the waters of which may be used for the cutting or harvesting of ice, any carcasses of any dead animal or any offal or offensive matter whatsoever, calculated to render said waters impure or create noxious or offensive smells, or shall connect any water-closet with any sewer or other means whereby the contents thereof may be conveyed to and into any such creek, pond, or brook, shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding one hundred dollars, or imprisonment not exceeding thirty days, or both.

[2 General Statutes, p. 2215.]

AN ACT to enable towns and townships in this State to construct waterworks for the extinguishment of fires and supplying the inhabitants thereof with pure and wholesome water. (Approved March 9, 1893.)

419. SEC. 13. That if any person or persons shall willfully pollute or adulterate the waters in any reservoir erected under the provisions of this act, any person so offending shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding five hundred dollars, or by imprisonment at hard labor not exceeding three years, or both, at the discretion of the court before whom such conviction shall be had.

[General Statutes, p. 1107.]

Supplement to an act to prevent the willful pollution of waters of any of the creeks, ponds, or brooks of this State. (Approved February 27, 1880.)

SECTION 1. (As amended by act passed March 14, 1893. General Statutes, p. 1107, sec. 311.) That if any person or persons shall throw, cause or permit to be thrown into any reservoir, or into the waters of any creek, pond, or brook of this State which runs through or along the border of any city, town, or borough of this State, or the waters of which are used to supply any aqueduct or reservoir for distribution for public use, any carcass of any dead animal, or any offal or offensive matter whatsoever calculated to render said waters impure, or to create noxious or offensive smells, or shall connect any water-closet with any sewer, or other means whereby the contents thereof may be conveyed to and into any such creek, pond, or brook, or shall so deposit or cause or permit to be deposited any such carcass, offal, or other offensive matter that the washing or waste therefrom shall or may be conveyed to and into any such creek, pond, brook, or reservoir, such person or persons shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding one thousand dollars, or by imprisonment not exceeding two years, or both.

309. SEC. 2. That it shall be the duty of the owner or owners, occupant or occupants of any land whereon any such carcass, offal, or other offensive matter may be to cause the same to be buried forth-

with, so that all portions thereof shall be covered with solid earth to a depth of at least two feet below the surface of the ground, and not within a distance of two hundred feet from such creek, pond, or brook used as aforesaid; and any such owner or occupant who shall refuse or neglect for the space of two days to remove and bury as aforesaid, or cause to be removed and buried, any such carcass, offal, or offensive matter shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding one thousand dollars, or by imprisonment not exceeding two years, or both.

[Laws of 1898, chap. 136, p. 233.]

AN ACT authorizing the appointment of commissioners to consider the subject of the pollution of rivers and streams within this State, to provide a plan for the prevention thereof, and for the relief of the persons and property affected thereby, and to provide for the expenses necessary for that purpose.

Be it enacted by the senate and general assembly of the State of New Jersey:

1. The governor of this State shall have power and authority to appoint and commission not less than three suitable persons commissioners to consider the subject of the pollution of any stream or river within this State, whose duty it shall be, after having duly investigated the cause, character, and extent of such pollution, if they shall deem it necessary and expedient, to prepare and perfect a plan for the prevention thereof and for the relief of the persons and property affected thereby, and to report their conclusions and present their plan to the legislature of this State, together with a bill providing therefor and for the expenses thereof.

2. Such commissioners, when so appointed, shall organize by the selection of one of their number as chairman and one to act as treasurer, and they are authorized to select a clerk and to employ such other agents and assistants as may be necessary. The salary and compensation of such commissioners shall be fixed by the governor, and shall not exceed one thousand dollars each, and they shall have power and authority to fix the compensation of their agents and assistants.

3. Such commissioners are authorized to raise and expend for the purposes of this act a sum not exceeding twenty-five thousand dollars, which sum, or such part thereof as may be required and be necessary, they are hereby authorized to apportion among the several local municipalities which the said commissioners shall deem to be affected by such pollution, in proportion to the population of such municipalities as shown by the last State or National census, and the sum or sums so apportioned shall be certified by the said commissioners under their hands to the assessors or other taxing officers of the said several municipalities, and it shall be the duty of the proper taxing

officer or officers in each of the said municipalities to whom such apportionment is made to proceed to have the same levied and assessed and collected in the same manner and at the same time as other taxes are levied and collected therein, and it shall be the duty of the collector or other equivalent officer of each of the said municipalities to pay over the said several sums of money, when so levied, assessed, and collected, to the said commissioners or to such person or persons as they may appoint to receive the same, and the said commissioners are authorized to use and disburse the same for the purposes of this act.

4. The commissioners appointed under the authority of this act shall have the power and authority to anticipate the collection and receipt of the sums of money hereby authorized to be raised by taxation, and may issue from time to time certificates of indebtedness, or other obligations, to be paid from the funds to be raised by taxation in the manner herein provided; and they are authorized to use the funds received from the sale or negotiation of such certificates or obligations authorized to be issued by this act.

5. Said commissioners are hereby required, at any time, on the order of the governor, to render to him a report and statement of their receipts and expenditures under the authority of this act.

6. Vacancies caused by the death or resignation of any commissioner appointed under the authority of this act, or from other cause, shall be filled by the governor, and the governor may remove any of the persons so appointed and appoint another commissioner in his place.

7. This act shall take effect immediately.

Approved April 2, 1898.

[Laws of 1899, chap. 41, p. 73.]

AN ACT to secure the purity of the public supplies of potable waters in this State.

Be it enacted by the senate and general assembly of the State of New Jersey:

1. No sewage, drainage, domestic or factory refuse, excremental or other polluting matter of any kind whatsoever which, either by itself or in connection with other matter, will corrupt or impair, or tend to corrupt or impair, the quality of the water of any river, brook, stream, or any tributary or branch thereof, or of any lake, pond, well, spring, or other reservoir from which is taken, or may be taken, any public supply of water for domestic use in any city, town, borough, township, or other municipality of this State, or which will render, or tend to render, such water injurious to health, shall be placed in, or discharged into, the waters, or placed or deposited upon the ice, or

any such river, brook, stream, or any tributary or branch thereof, or of any lake, pond, well, spring, or other reservoir above the point from which any city, town, borough, township, or other municipality shall or may obtain its supply of water for domestic use, nor shall any such sewage, drainage, domestic or factory refuse, excremental or other polluting matter be placed or suffered to remain upon the banks of any such river, brook, stream, or of any tributary or branch thereof, or of any lake, pond, well, spring, or other reservoir above the point from which any city, town, borough, township, or other municipality shall or may obtain its supply of water for domestic use as aforesaid; and any person or persons, or private or public corporation, which shall offend against any of the provisions of this section shall be liable to a penalty of one hundred dollars for each offense; and each week's continuance, after notice by the State or local board of health to abate or remove the same, shall constitute a separate offense: *Provided, however*, That this section shall not be held to apply to any city, town, borough, township, or other municipality of this State which, at the date of the passage of this act, has a public sewer or system of sewers, drain or system of drains, legally constructed under municipal or township authority, discharging its drainage or sewage into any such river, brook, stream, lake, pond, well, spring, or other reservoir: *And provided further*, That nothing in this section contained shall be construed to repeal, modify, or otherwise affect any law or statute now conferring upon any local board of health the power or authority to institute any proceedings in any court of this State for the recovery of any penalty for, or obtaining any injunction against, the pollution of any of the waters of this State.

2. Any penalty incurred under any of the provisions of the first section of this act may be recovered, with costs, in a summary proceeding, either in the name of the board of health of the State of New Jersey or in the name of the local board of health of the township, city, borough, town, or other local municipal government within whose jurisdiction the penalty may have been incurred; it shall be the duty of any health inspector, or member of any local board of health, who shall know or be informed of any violation of any of the provisions of the first section of this act whereby any penalty may have been incurred, to make, and any other person having such knowledge may make, under oath or affirmation, a complaint against the person or persons or private or public corporation incurring such penalty, setting forth the facts of such violation, which complaint shall be filed in the office of the clerk of the district court, or with any justice of the peace of the county within which the offense may have been committed, or with any police justice or recorder of the township, city, or other municipality within which any local board bring-

ing suit shall have jurisdiction; and the district court, justice of the peace, police justice, or recorder, with whom any complaint shall be filed as aforesaid, setting forth facts sufficient to show that the penalty prescribed by the first section of this act has been incurred, is hereby authorized and required to issue process either in the nature of a summons or warrant, which process, when in the nature of a warrant, shall be returnable forthwith, and when in the nature of a summons shall be returnable in not less than five nor more than fifteen days. On the return of such process, or at any time to which the trial shall have been adjourned, the said court, justice of the peace, police justice, or recorder shall proceed to hear the testimony of witnesses and the proofs in the case, and to determine and give judgment in the matter without the filing of any pleadings, and, if judgment shall be given in favor of the plaintiff, execution shall forthwith issue against the goods and chattels of the defendant for the amount of the penalty, with costs; and all judgments so rendered shall have the same force and effect as other judgments in civil actions before civil courts and officers, and may be docketed in like manner in the office of the clerk of the court of common pleas; the officers to serve and execute any process or execution issued as aforesaid shall be the constables of the counties, which service and execution, in the case of any execution issued out of the district court, shall be made in the same manner and under the same liabilities as other executions issued out of said court are served and executed; the officers to serve and execute any process or execution issued by a justice of the peace, police justice, or recorder, shall be the constables of the county, which service and execution shall be made in the same manner and under the same liabilities as prescribed in cases of the service and execution of processes and executions by the act entitled "An act constituting courts for the trial of small causes," and the supplements thereto; all moneys recovered in any such proceeding shall be paid to the plaintiff therein and applied by such plaintiff to any purpose for which it may be legally authorized to expend money.

3. The State board of health shall have the general supervision, with reference to their purity, of all rivers, brooks, streams, lakes, ponds, wells, springs, or other reservoirs in this State the waters of which are or may be used as the source or sources of public water supplies for domestic use, together with the waters feeding the same, and shall have the authority from time to time, as they deem necessary or proper, to examine the same and to inquire what, if any, pollutions exist and their causes: and the said State board of health, in carrying out the provisions of this section, may from time to time, as they deem it necessary or proper, address inquiries in printed or written form to any local board of health, municipal or township authority, corporation, or person or persons, which inquiries it shall

be the duty of the persons or parties addressed to answer within such time as the said State board of health may in such inquiries prescribe.

4. If any person or persons, corporation or corporations, city, town, borough, township, or other municipality of this State, or any municipal or township authority, shall violate any of the provisions of the first section of this act, it shall be lawful for the said State board of health, instead of proceeding in a summary way to recover the penalty prescribed in said section, to file a bill in the court of chancery, in the name of the State, on the relation of such board, for an injunction to prohibit the further violation of the said section, and every such action shall proceed in the court of chancery according to the rules and practice of bills filed in the name of the attorney-general on the relation of individuals, and cases of emergency shall have precedence over other litigation pending at the time in the court of chancery, and may be heard on final hearing within such time and on such notice as the chancellor shall direct.

5. All acts and parts of acts inconsistent with the provisions of this act are hereby repealed.

6. This act shall take effect immediately.

Approved March 17, 1899.

[Laws of 1899, chap. 210, p. 536.]

AN ACT to prevent the pollution of the waters of this State by the establishment of a State sewerage commission, and authorizing the creation of sewerage districts and district sewerage boards, and prescribing, defining, and regulating the powers and duties of such commission and such boards.

Be it enacted by the senate and general assembly of the State of New Jersey:

1. It shall be the duty of the governor, within thirty days next succeeding the approval or passage of this act, to appoint, by and with the advice and consent of the senate, five citizens of this State, to compose and be known as "the State sewerage commission." In the original nomination of the members of said commission to the senate the governor shall designate one of them to serve for one year, and two for two years, and two for three years, and thereafter the members of said commission shall be appointed by the governor, by and with the advice and consent of the senate, for the term of three years and until their successors are duly appointed, confirmed, and qualified. Any vacancy occurring in said commission when the legislature is not in session shall be filled by appointment of the governor until the next regular session of the legislature, when such vacancy shall be filled in the manner hereinbefore provided, but any such last-mentioned appointment and confirmation by the senate shall be for the unexpired term only. Members of said commission, before enter-

ing upon the duties of their office, shall make and subscribe an oath or affirmation (before some person authorized by the laws of this State to administer the same) to truly, faithfully, and impartially perform and discharge the duties of their office according to law and file the same with the secretary of state. The terms of office of the members of said commission (except those appointed by the governor to fill vacancies as aforesaid) shall commence on the first Monday of May next succeeding their appointment by the governor and confirmation by the senate. On the first Monday of May next succeeding the original appointment of said commission the members thereof shall meet at the statehouse in the city of Trenton and organize by the election of one of their number to be chairman of said commission and one to be treasurer thereof, which officers shall hold office at the pleasure of the commission. After having so met and organized subsequent meetings of the commission shall be held at such times and places as the commission may direct or as it may be called to meet by the chairman.

2. Said commission shall keep a record of all its proceedings and transactions, also full and accurate account of its receipts, disbursements, expenditures, assets, and liabilities, and shall annually report to the legislature its operations, proceedings, and transactions for the preceding year, with a statement or abstract of such receipts, disbursements, expenditures, assets, and liabilities.

3. The members of said commission shall each receive an annual salary of one thousand dollars, to be paid as other salaries of State officers are paid. Said commission may have a secretary (not a member of the commission), to be appointed by the commission or a majority thereof, who shall hold his office at the pleasure of the commission or a majority thereof, and receive such salary as the commission or a majority thereof, with the approval of the governor, may fix; said commission or a majority thereof may also from time to time employ or appoint such experts, engineers, officers, agents, employes, workmen, and servants as it may deem necessary or proper to enable it to perform its duties and carry out the objects and purposes of this act; and said commission or a majority thereof may fix and determine the duties and compensation of said experts, engineers, officers, agents, employes, workmen, and servants, and remove or discharge the same or any of them at pleasure.

4. It shall be the duty of the secretary to keep a record of all the proceedings and transactions of the commission, to prepare the annual report to the legislature, and perform such other duties as the commission may require. It shall be the duty of the treasurer to take charge of the moneys received by the commission, to keep accurate accounts of the receipt and disbursement thereof, and to deposit and

pay out said moneys as the commission may direct and under such rules and regulations as it may from time to time establish. The treasurer may be required to give bond to the commission for the due and faithful performance of his duties as such treasurer, in such sum and with such sureties as the commission or a majority thereof may require and approve.

5. It shall be the duty of said commission to investigate the various methods of sewage disposal, either in this country or elsewhere, in order that they may be able to make proper recommendations in regard thereto. They shall investigate all complaints of pollution of the waters of this State which shall be brought to their notice, and shall advise as to the best methods of sewage disposal in order to prevent such pollution.

6. It shall be unlawful for any person, corporation, or municipality to build any sewer or drain or sewerage system from which it is designed that any sewage or other harmful and deleterious matter, solid or liquid, shall flow into any of the waters of this State so as to pollute or render impure said waters, except under such conditions as shall be approved by the State sewerage commission: *Provided*, That the provisions of this section shall not be deemed to prohibit the use or extension of existing sewers, drains, or sewerage systems.

7. It shall be unlawful for any person, corporation, or municipality to build or cause to be built any plant for the treatment of sewage or other polluting substance from which the effluent is to flow into any of the waters of this State, except under such conditions as shall be approved by the State sewerage commission, to whom the plans shall be submitted before building.

8. On or before the first day of January, one thousand nine hundred, and thereafter whenever required by said commission, the mayor of every municipality and the chairman of every township committee of every township now having, using, owning, leasing, or controlling a sewerage plant or system shall furnish to said commission, on blanks to be provided by said commission, a statement showing the disposition made of the sewage of their respective municipalities or townships, and, as near as possible, the amount discharged each twenty-four hours, and such other information and data as may be called for by said blanks to be provided as aforesaid by said commission.

9. The words "waters of this State," as used in this act, shall be held and construed to mean and include any and all waters of any pond, lake, creek, inlet, bay, estuary, river, or stream of this State.

10. To enable said commission to carry out and enforce the provisions of this act, the said commission may expend a sum not exceeding five thousand dollars, when duly appropriated.

11. And whereas, in order to prevent the pollution of the waters of this State, it is deemed necessary to establish a proper system or sys-

tems of sewerage and drainage wherein may or may not be included a system or systems of sewage-disposal works for the scientific treatment and proper disposal of sewage and sewage matter and the effluent thereof, and the establishment of any such system or systems may render proper or necessary the formation or creation of sewerage districts embracing portions or the whole of the territory of two or more of the municipalities of this State, within which districts such system may be constructed, maintained, and operated, and such municipalities may be unable, through lack of power and authority or otherwise, to agree upon the establishment of any such system or systems or upon the extent or limits of the territory of their respective municipalities to be included in any such district or districts and devoted to the uses and purposes of any such system or systems as aforesaid; therefore upon presentation to said the State sewerage commission of a petition in writing, setting forth that in order to prevent the pollution of the waters of this State, or any of them, it is proper or necessary that portions or the whole of the territory of two or more of the municipalities of this State should be erected into a sewerage district for the construction, maintaining, and operation within such district of a system of sewerage and drainage or a system of sewage-disposal works, or of both such systems, and naming each municipality, the whole or any portion of the territory whereof it is proposed shall be included in such district, and stating generally the boundaries and outlines of such proposed district with sufficient exactness to show approximately the quantity or extent of territory of each municipality to be embraced in such proposed district, and requesting said commission to create and establish such district for either or both of the purposes aforesaid; and if said petition be signed by the mayors or other chief executive officers of all of the municipalities named in said petition, any of whose territory is proposed to be included in said district, said signatures being respectively affixed to said petition by authority or direction of the respective governing bodies of such municipalities (full power and authority to authorize and direct the signing of any such petition being hereby conferred upon and vested in all such governing bodies), and the signing of said petition by such authority or direction being made to appear by affidavit or other due proof thereof, it shall be lawful for said the State sewerage commission to appoint a time and place when and where it will attend and give public hearing of the matters contained in said petition to all persons and parties interested therein; said commission shall cause at least twenty days' notice to be given of the time and place of any such hearing by publishing the same in the newspaper or newspapers, if any, published within said proposed district, and if none be published therein, then in a newspaper or newspapers published in the neighborhood of said proposed district and

circulating therein; said notice may also, at the discretion of said commission, be published in a newspaper or newspapers published outside of said proposed district, whether or not any paper or papers be published within the same; said commission shall also, at least ten days prior to the day fixed for such hearing, cause notice of the time and place thereof to be mailed to or served upon the mayor or other chief executive officer of any and all municipalities named in said petition, any territory whereof is included in said proposed district; and said commission may, if it deem proper so to do, require a copy of said petition to be mailed to or served upon such mayors or other chief executive officers such number of days prior to said hearing as it may direct; said hearing may be adjourned from time to time as said commission may decide; the sessions of said commission on said hearing, or any adjournment thereof, when sitting for the taking of testimony or hearing argument of counsel, shall be open and public, and witnesses may be examined under oath or affirmation, which any member of said commission or the secretary thereof is hereby authorized and empowered to administer; the secretary of said commission shall attend at all such hearings and keep minutes of the proceedings thereat; said commission may, if it deem proper so to do, employ a stenographer to take and transcribe the testimony produced before it at any such hearing; and said commission may require the persons or parties presenting to it any such petition as aforesaid to pay in advance or assume or guarantee to pay all or such part of the costs, charges, and expenses to be made or incurred by reason of the filing of said petition and subsequent proceedings to be had thereupon or thereunder, as said commission may think proper.

12. If, after such hearing, said commission, or a majority thereof, shall deem it advisable to comply with the request of said petition, and that a district for the purpose or purposes, or either of them therein stated, should be created and established, said commission shall adopt a resolution to that effect, defining the limits and boundaries of such district with certainty and declaring the territory included within such limits and boundaries to be a sewerage district, within which a system of sewerage and drainage, or a system of sewage-disposal works, or both, may be constructed, maintained, and operated under the provisions of this act; the said districts shall be called and known as "sewerage districts," and the boards to construct, maintain, and operate the system or systems of sewerage or sewage-disposal works within such districts shall be called and known as "sewerage boards;" in and by said resolution, said commission shall assign to the district therein and thereby established a name and number, thus, "Sewerage district number ——," and shall also specify the name by which the board thereafter to be elected in such

district shall be called and designated, thus, "Sewerage board of district number ——," the number of any such district and that of the sewerage board therein to be always the same. The first sewerage district created and established under this act shall be "Sewerage district number one," the second number two, and so on in regular order as the same may be respectively created. Said commission shall also cause a map to be prepared of said district so created and established, whereon and whereby shall be shown with accuracy the limits and boundaries of such district, of what municipalities the lands included in said district form a part, and what extent or quantity of territory of each municipality (whether the whole or a portion thereof) is included in said district. The original of said map shall be filed with said commission, and within ten days after the adoption of said resolution a copy thereof and of said map shall be filed in the office of the secretary of state and in the clerk's office of each county in which any of the lands included in said district may be situate; and from and after the filing of such resolution and maps as aforesaid the territory included in said district as stated and shown in and by said resolution and map shall be deemed to be and constitute a sewerage district by the name and number and for the purposes stated in said resolution.

13. The members of the several sewerage boards shall consist of two members from each municipality, in whole or part, within the sewerage district, to be appointed by the governing body of each of such municipalities, and one member to be appointed by the State sewerage commission, all of whom shall be residents of the district; provided that in case more than three municipalities shall be included in whole or part in any sewerage district there shall be but one member from each municipality in addition to the number appointed by the State sewerage commission.

14. The members of any district sewerage board first appointed shall meet at such time and place as the State sewerage commission shall designate; each member of said board (and all members thereof afterwards appointed thereto) shall take and subscribe an oath or affirmation, before some person authorized to administer the same, to faithfully and truly perform his duty as member of such board to the best of his ability, and within two days after making thereof forward the same to the secretary of state; said board when met as aforesaid (the members thereof having each made and subscribed said oath or affirmation) shall organize by the election of one of their number as chairman, one as secretary, and one as treasurer; the members of said board shall serve for the term of three years each, and the terms of such members shall commence on the date of their first meeting as

designated by the State sewerage commission; the chairman, secretary, and treasurer of said board shall, respectively, serve for the period of one year and until their successors are elected; a certificate or statement of such meeting and organization of said board shall, on the day of such meeting, be prepared and mailed to the secretary of state, to be filed in his office; meetings of said board subsequent to such first meeting for organization shall be held at such times and places as the board may decide or as it may be called to meet by the chairman.

15. From and after such meeting and organization of said board and the filing of such certificate as aforesaid, said board shall be deemed to be and shall be a body politic and corporate, under the same name and title as that designated and specified in the resolution of the State sewerage commission creating and defining the said sewerage district, to wit, "Sewerage board of district number ——," and by such name and title said sewerage board shall have perpetual succession, with power to sue and be sued, and the right, power, and authority to acquire, hold, use, and dispose of all such property, real or personal, as may be proper or necessary for the objects, uses, and purposes for which said sewerage board was created, and with all other powers necessary or incident to bodies politic and corporate or that may be necessary or proper to carry out and effectuate the objects and purposes of this act and the objects and purposes for which said sewerage board was created.

16. Any such board incorporated as aforesaid shall have full power and authority within its respective district, under the supervision, direction, and control of the State sewerage commission as hereinbefore or hereinafter provided, to construct, maintain, and operate in said district a system of sewerage and drainage, or of sewage-disposal works, or both, with the necessary pipes, drains, conduits, fixtures, pumping works, and other appliances for the purpose of taking up sewage and all other offensive and deleterious matter and convey the same to some proper place or places of deposit or disposal to be selected by the said board, there to be deposited, treated, disinfected, or disposed of as to the said board may seem proper and as may be deemed most advantageous; and it shall be the duty of all persons and all corporate bodies and municipalities owning or controlling sewers or drains or having charge thereof within the limits of the district wherein intercepting or main sewers have been or may be constructed by the said board as herein provided, to cause the same to be connected therewith; and it shall be the duty of said board in constructing such main or intercepting sewers to have them so constructed that such connection can be made therewith at all necessary and proper points and places; all such connections shall be made in

accordance with the rules and regulations from time to time adopted by the said board in relation thereto, and under the direction and supervision of its officers and agents.

17. The said board shall have power and authority to purchase and acquire all lands, rights, or interest in lands which may be deemed necessary for the construction of sewers, drains, disposal pumping, and other works authorized by this act; and if in any case the said board shall be unable to agree with the owner or owners of any lands, rights, or interests in lands deemed necessary by the said board in the construction of the works herein authorized, or when, by reason of the legal incapacity or absence of such owner or owners, no agreement can be made for the purchase thereof, the lands or rights in lands so desired shall be acquired in the manner provided by the general laws of this State relating to the condemnation of lands for public use.

18. Before determining upon the final plan or route for the building or construction of any work authorized by this act, the said board may, by its officers, agents, servants, and employés, enter at all times upon any lands or waters for the purpose of exploring, surveying, leveling, and laying out the route of any drain or sewer, locating any disposal, pumping, or other works, establishing grades and doing all necessary preliminary work, doing, however, no unnecessary damage or injury to private or other property.

19. The said board shall have power and authority to construct any sewer or drain, by it to be made or constructed under or over any water course, under, over, or across, or along any street, turnpike, road, railroad, highway or other way, and in or upon private or public lands under water, in such way and manner, however, as not unnecessarily to obstruct or impede travel or navigation, and may enter upon and dig up any road, street, highway, or private or public land, for the purpose of laying down sewers and drains upon or beneath the surface thereof, and for maintaining and repairing the same, and in general may do all other acts and things necessary, convenient, and proper for the purposes of this act; and whenever the said board shall dig up any road, street, or way, as aforesaid, it shall, as far as practicable, restore the same to as good condition and order as the same was when such digging commenced.

20. The said board shall have power and authority also to alter or change the course or direction of any water course, and, with the consent of the board or body having control of the streets and highways in any city, town, or municipality, to alter or change the location or grade of any highway, public street, or way crossed by any sewer or drain constructed or to be constructed under the provisions of this act, or in which such sewers or drains may be located.

21. The said board shall at all times keep full and accurate accounts of its receipts, expenditures, disbursements, assets, and liabilities, and shall annually make a report of its operations and doings, in which report it shall include an abstract of such receipts, expenditures, disbursements, assets, and liabilities, and publish the same in one or more newspapers, published in each of the counties in said district.

22. To provide for the payment of the costs and expenses incurred or to be incurred by the said board in making the constructions and executing the work and performing the duties imposed upon it by this act, it shall have power and authority from time to time to issue bonds in its corporate name, not to exceed in amount such costs and expenses, and not to exceed that part of such cost and expense incurred in the work of constructing sewers, drains, disposal, and other works, including the cost of lands, rights and interests in lands, of which a separate account is to be kept by said board as hereinafter provided; such bonds shall be of the form and payable at such time, not exceeding thirty years from the date thereof, and at such place, either in currency or coin, as the said board may determine; they shall bear interest at a rate not exceeding five per centum per annum; in issuing such bonds the said board may, in its discretion, make the same or any part thereof, fall due at stated periods less than thirty years, or may reserve therein an option to redeem and pay the same or any part thereof at stated periods at any time between the date thereof and the date at which they would otherwise fall due, and all such bonds may be negotiated, sold, or disposed of at not less than their par value, and the same or the proceeds thereof may be used by the said board for the purpose aforesaid.

23. The said board shall keep the costs and expenses of the construction of sewers, drains, disposal and other works, in which shall be included the cost of lands, rights, and interests in lands, separate from the costs and expenses of maintenance, operation, and repairs, and shall, after having prepared and adopted plans (which, however, the board or the State sewerage commission shall have the power to change or modify, if such change or modification shall be found necessary or desirable), make a careful estimate of the cost and expense of such construction, and shall divide and apportion the same, according to their best judgment, to and between the several municipalities or parts thereof (if any) included within such sewerage districts ratably and proportionally to the benefits received or to be received by such municipalities or parts thereof from such construction, and shall furnish to the governing body of each and every municipality the whole or any part whereof is included in such sewerage district, a statement of such estimated cost and expense and of the division and

apportionment thereof as aforesaid, and service of said statement upon the mayor or other chief executive officer or upon the clerk of any such municipality shall be deemed to be a service upon the municipality; if the governing body of any such municipality (whether a whole or only a part thereof is included in such sewerage district) shall be dissatisfied with such division and apportionment and shall within twenty days after service thereof as aforesaid express such dissatisfaction by a resolution adopted by a majority of such body, then it shall be lawful for such body, in the corporate name of such municipality, to make application to any justice of the supreme court of this State for the appointment of three disinterested persons, residents of this State, commission to review such division and apportionment, and correct, amend, revise, alter, or confirm the same, as they or a majority of them shall deem just and proper, and it shall be the duty of said justice to make such appointment; the commissioners so appointed (having respectively taken and subscribed an oath or affirmation before some person authorized to administer the same faithfully and impartially to perform the duties imposed upon them by [a]), shall forthwith, at such time and place as they or a majority of them may appoint, and upon such notice as the said justice in the order appointing said commissioners shall direct to be given, hear the parties interested in said matter and such proofs and witnesses as may be produced before them; said commissioners may adjourn said hearing from time to time as occasion may require; on any such hearing the parties, if they so choose, may be represented by counsel, and the witnesses may be examined under oath or affirmation, which any of said commissioners are hereby authorized to administer; said commissioners may designate one of their number to act as chairman and one to act as clerk or secretary; at the conclusion of such hearing, and within ten days thereafter, said commissioners, or a majority of them, shall correct, amend, revise, alter, or confirm such division and apportionment as they or a majority of them shall deem just and proper under the evidence and proofs produced before them and shall make and sign a statement or certificate thereof, which statement or certificate shall be final and conclusive and binding upon all parties; the application for the appointment of such commissioners, the order of the justice appointing them, the oath or affirmation of said commissioners, and their said statement or certificate shall, within two days after the making of such statement or certificate, be filed with the secretary of the sewerage board which made the division or apportionment reviewed by said commissioners; and such sewerage board, within five days after the filing of such statement or certificate as aforesaid, shall cause a certified copy thereof to be served in manner

a So in original.

aforesaid upon each of the municipalities that the original division and apportionment made by said sewerage board was served upon, which certified copy so served shall be in lieu and stead of that originally served and (as aforesaid) be final and conclusive and binding upon all parties; if, in any case, where only a part of a municipality is included in a sewerage district, the governing body of such municipality shall not within said twenty days after service upon it of any such original statement as aforesaid adopt a resolution expressing its dissatisfaction as aforesaid provided, then, and in every such case, it shall and may be lawful for one or more of the residents and taxpayers, or residents and nonresident taxpayers of said sewerage district, to join in such application as aforesaid to any justice of the supreme court for the appointment of commissioners to review, as aforesaid, the said division and apportionment, and thereupon the said justice may, in his discretion, appoint such commissioners, and if such appointment be made, said commissioners shall proceed in the same manner, and the proceedings before them had shall be similar to those hereinbefore provided, and the statement or certificate of said commissioners made upon any such last-mentioned application shall be final and conclusive and binding upon all parties.

24. The said sewerage board shall also, in the manner hereinbefore directed, serve upon or furnish to each of said municipalities after every issue and sale of bonds a statement of the amount of such bonds and the date of interest thereon and the proportion thereof allotted to each municipality (where such municipality is entirely within the sewerage district) or (where only a part of the municipality is included in the sewerage district) of the proportion of such division and apportionment allotted to the part of the municipality in said sewerage district; and it shall be the duty of each of said municipalities, and of its proper officers, in the next annual tax levy made in such municipality and in each succeeding year thereafter to include and raise by taxation the amount required to pay the interest on the proportion of such bonded indebtedness allotted to such municipality or part thereof, as the case may be, and if such municipality be entirely within such sewerage district then it shall be the duty of such municipalities to cause to be levied and assessed therein a sum equal to the amount of interest so apportioned and allotted to such municipality together with such additional sum, to be divided and apportioned and allotted to and between said municipalities or parts thereof as aforesaid as may be necessary to establish and maintain a sinking fund sufficient to pay the principal of the bonds issued by the said sewerage board under authority of this act when the same fall due. If only a part of the municipality be included in the sewerage district, then it shall be the duty of such municipality and its

proper officers, instead of levying and assessing the same upon the whole municipality, to cause, in manner aforesaid, the sum or sums that may, as aforesaid, be apportioned and allotted to such part of the municipality as is included in the sewerage district to be levied and assessed in and upon such part of the municipality as is included in the sewerage district, in the same manner as other taxes may be levied and assessed therein; and it shall be the duty of all taxing officers and all collecting officers in the said municipalities to levy, assess, and collect the said amount or sums so to be raised in such municipalities or parts thereof, as the case may be; and it shall also be the duty of the collector of taxes in each of the said municipalities, or other proper officer, to pay to the sewerage board thereunto entitled the money so levied, assessed, and collected. After each census, State or national, a new allotment shall be made of the sinking fund or redemption fund in the manner herein provided.

25. As soon as the work of construction by this act authorized (or the cost and expense of which a preliminary estimate shall have been made as herein provided) has been completed the said board shall proceed at once to ascertain the actual cost and expense of such work, and shall furnish to each of the said municipalities or municipal divisions a statement of such cost and expense.

26. The cost of maintenance, operation, and repairs, together with the cost of supervision, and all other expenses of every kind not included in the cost and expense of construction, shall be annually estimated by the said board and divided and apportioned between the said several municipalities or parts thereof upon the same basis as herein provided for the division of the cost and expense of construction; and that the same, when so divided and apportioned, shall be levied, assessed, collected, and paid annually in the same manner provided for the levying, assessment, and collection of the cost and expense of construction: *Provided, however*, That if at the end of any year when such cost and expense shall have been accurately ascertained such estimate shall be found to have been more or less than the proper proportion of any such municipality, then the surplus or deficiency, as the case may be, shall be deducted from or added to the sum to be levied, assessed, and collected for the succeeding year.

27. The said board shall, immediately after receiving from the said municipalities, or either of them, or from the collector or treasurer of any such municipality, any moneys on account of the apportionment made, as hereinbefore provided, or as soon thereafter as practicable, cause the same to be invested in securities, the character of which shall be the same as required by law for savings banks of this State, except so much thereof as may be required to pay interest due or to fall due during the current year; and all such funds, and the

securities in which the same or any part thereof shall be invested, and the interest received therefrom, shall be held, used, and applied by the said board as a sinking fund to meet and pay the interest and principal on the bonds issued by the said board under the authority of this act, and for no other purpose whatever, until all such bonds and all arrears of interest thereon are fully paid. It shall be the duty of said sewerage board to include in its annual report the amount of money received by it for the purposes aforesaid, the sources from which such money was received, and the investment of the same; and the said board shall keep a record and account of all bonds issued by it, when the same fall due, the time and place of payment, and the rate of interest thereon, and of the amount received on the sale or disposition thereof, and shall also keep an account of all moneys invested, held, and used as a sinking fund, and of the securities in which the same may be invested. The books, records, accounts, papers, and documents of the said board shall be open to the inspection of any person appointed by the governing body of any municipality within said district to inspect the same: *Provided, however*, That in case the said board shall issue bonds which shall fall due and become payable at stated periods less than thirty years, or shall retain in any such issue the option to redeem bonds prior to the date at which they would otherwise fall due as hereinbefore provided, then it shall be lawful for the said board to make application of the moneys received by it from the several municipalities and of the funds temporarily invested by the said board so received for the purpose of paying off and discharging the said obligations according to their tenor and effect.

28. During the year preceding the year in which the bonds issued under the authority of this act shall fall due the said board shall cause a careful computation to be made of the moneys that will be available for the payment of the same, and if it shall be found that any deficiency will exist in the fund that will be available therefor, after the application of moneys received and the use of all securities held, such deficiency shall be apportioned and allotted to the said municipalities in the same manner and upon the same basis as the original apportionment, and shall be added to the amount so levied, assessed, collected, and paid by the said municipalities, respectively, in the succeeding year; and if any excess shall be found to exist in such fund the surplus shall be credited to each of the said municipalities in the same proportion and deducted from future estimates of the respective shares or proportions of such municipalities of the cost and expense of maintenance, operation, and repairs.

29. In and about the performance and discharge of the duties imposed upon it by this act any such sewerage board as aforesaid,

or a majority thereof, may employ such experts, engineers, contractors, officers, agents, employes, clerks, workmen, and servants as it may deem necessary or proper to enable it to perform its duties and carry out the objects and purposes of this act; and said board, or a majority thereof, may fix and determine the duties and compensation of such experts, engineers, contractors, officers, agents, employees, clerks, workmen, and servants, and remove or discharge the same, or any of them, at pleasure.

30. The secretary of any such sewerage board shall keep a record of all the proceedings and transactions of said board; under the direction of said board he shall prepare the estimate, division, and apportionment provided for in section twenty-six hereof; he shall prepare the annual report of said board and perform such other duties as the board may from time to time require. The secretary shall receive an annual salary, to be fixed by the board, or a majority thereof, but he shall not receive any per diem allowance.

31. The treasurer of any such sewerage board shall have charge and custody of all moneys and securities received or owned or held by said board; he shall keep accurate record and account of the receipt, disbursement, and disposition of all such moneys and securities, and invest, deposit, dispose of, disburse, and pay out the same at such times and in such manner as the board may direct, and under such rules and regulations as it may from time to time establish. The treasurer shall give bond to such board for the due and faithful performance of his duties as such treasurer in such sum and with such sureties as the board, or a majority thereof, may require. The treasurer shall receive an annual salary, to be fixed and determined by the board, or a majority thereof, but he shall not receive any per diem allowance.

32. The members of any such board, except the secretary and treasurer thereof, when actually engaged in and about the business of said board, shall receive a per diem compensation of five dollars; said per diem compensation, and the salaries to be paid the secretary and treasurer, shall be included in said estimate hereinbefore mentioned.

33. Any such sewerage board is authorized and empowered to rent an office or offices as may be required for the due transaction and carrying out of its work and duties, and to properly equip and furnish such office or offices, the expense thereof to be included in said estimate mentioned in section twenty-six hereof.

34. This act shall take effect immediately.

Approved March 24, 1899.

[Laws of 1902, p. 195, chap. 49.]

AN ACT authorizing the appointment and defining the powers and duties of commissioners in sewage and drainage districts created for the purpose of relieving the streams and rivers therein from pollution, and to provide a plan for the prevention thereof, and providing for the raising, expenditure, and payment of moneys necessary for this purpose.

Be it enacted by the senate and general assembly of the State of New Jersey:

1. Upon the creation and incorporation by the legislature of any sewerage and drainage district for the purpose mentioned in the title of this act it shall be the duty of the governor of this State forthwith to appoint therein and therefor five able and discreet men, residents within such district (having regard in making such appointments to locality, so that each section of the district may be represented, as far as practicable), who, when so appointed, commissioned, and sworn, shall constitute a board of commissioners, to be known as the ——— district sewerage and drainage commissioners (inserting in each case in the blank space the name of the district designated in the act of incorporation), and the persons so appointed shall receive as compensation for their services an annual salary of twenty-five hundred dollars, payable in equal monthly installments. In making the first appointments under this act the members of the said board shall be appointed as follows: One for a term of one year, one for a term of two years, one for a term of three years, one for a term of four years, and one for a term of five years, and thereafter one shall be appointed each year for a term of five years. Any vacancy occurring in the said board by death, resignation, or otherwise, shall be filled in the same manner as the original appointment for the balance of the term. Each of the said commissioners so appointed shall, before they enter upon the duties of their office, take and subscribe an oath that they will faithfully and impartially execute and perform the duties imposed upon them by law, and cause the same to be filed in the office of the secretary of state of this State. The governor of this State shall have power to remove such commissioners from office for cause during their term of office and, upon removal, to fill the vacancy thus occasioned for the unexpired term in the manner herein provided for filling vacancies.

2. The said board shall, as soon as may be after appointment, and annually thereafter on the first Tuesday in May in each year, organize by the choice of one of its members as chairman, and may elect a clerk, who may or may not be a member of the said board, and may from time to time appoint such agents, officers, and servants and employ such engineers and assistants as it may deem necessary to

'arry out the purposes of this act, and may determine their duties ınd compensation and remove the same at its pleasure.

3. The said board of commissioners, when duly organized, shall be leemed to be and shall become a body corporate, with power to sue ınd be sued and with the right to acquire, hold, use, and dispose of ıll such property as may be necessary for the uses and purposes for vhich the said board was created and with all other necessary powers ncident to corporate bodies.

4. When duly organized, the said commissioners shall at once, with he aid and assistance of such engineers and other agents as they may leem proper, proceed to investigate methods and plans for relieving he streams and rivers within the said district from pollution and for ›reventing the pollution of the same, and to determine the apportionnent of the capacity of sewer provided for each municipality in any ntercepting sewer, sewers, or disposal works: *Provided*, That before ı final determination as to the plan or method to be adopted for the ›urpose, an opportunity shall be given the governing body of each nunicipality to be heard in relation thereto, and after said hearing, ıs soon as the said commissioners have adopted a plan or method for his purpose, they shall report the same to the respective municipalties of the district and to the legislature of this State, together with ı bill providing therefor and for the expenses thereof.

5. Before determining upon the final plan or route for the building ›r construction of any work investigated under this act the said ›oard may, by its officers, agents, servants, and employees, enter at all ;imes upon any lands or waters for the purpose of exploring, surveyng, leveling, and laying out the route of any drain or sewer, locating ıny disposal, pumping, or other works, establishing grades, and doing ıll necessary preliminary work in the way of designating locations, loing, however, no unnecessary damage or injury to private or other ›roperty.

6. The said board shall at all times keep full and accurate account ›f its receipts and expenditures, disbursements, assets, and liabilities, ınd shall annually cause a detailed statement thereof to be published n one or more newspapers published or circulating in the respective nunicipalities in said district.

7. To provide for the payment of the cost and expense incurred or ;o be incurred by the said board in investigating and performing the luties imposed upon it by this act, one-half of said cost of[a] expense ihall be paid out of the State treasury on certificate of the governor ;o the comptroller, who shall draw his warrant on the State treasurer ın favor of the said board for the amount thereof, the same to be

[a] So in original.

ascertained on a duly verified statement of such expenses being filed with the governor and in the office of the secretary of state; as to the balance of the said costs and expense incurred or to be incurred under this act, the said board shall have power and authority:

I. To issue from time to time, for the said one-half of the costs and expenses, temporary certificates, to run for a period not to exceed two years, the aggregate issue of said certificates not to exceed the sum of twenty-five thousand dollars; such certificates, when issued, shall be deemed and considered the indebtedness of the sewerage and drainage district, and shall constitute a charge upon persons and property therein, and shall be retired and paid in the manner hereinafter provided.

II. The said board shall have power and authority to order and cause a tax to be levied, assessed, and collected upon persons and property within the said sewerage and drainage district, the proceeds of which to be used in payment of the said certificates and the interest due and to grow thereon; the amount to be assessed and collected in the respective municipalities composing such districts shall be determined by the said board, and shall be apportioned according to the taxable ratables of the last preceding year as returned by the taxing officers in said district, and a certificate by the said board shall be filed with the taxing officers of such municipalities composing the said sewerage district, and it shall be the duty of the taxing officers within the said municipalities included in the said sewerage and drainage district, to levy, assess, and collect and pay over to the said commissioners any tax ordered by them to be assessed by virtue of the provisions of this act.

8. It shall be the duty of the said board annually to make and file with the secretary of state of this State a report showing the amount of money received by it for the purposes aforesaid, sources from which money was received, and the expenditure of the same; and it shall be the duty of the said board to keep an account of all certificates issued by it, when the same fall due, the time and place of payment, the rate of interest thereon, and of the amount received on the sale or disposition thereof; and the books, records, accounts, papers, and documents of the said board shall be open for the inspection of the governor of this State, or any person or persons whom he may appoint to inspect the same.

9. For the purpose of carrying out the provisions of this act with dispatch the sum of twenty-five thousand dollars is hereby appropriated by the State out of any moneys now in the State treasury not otherwise appropriated, and the governor is hereby authorized and empowered to give an order on the comptroller for advanced payments to the said board on account of the State's share of such expenses to be incurred.

10. When the said board of commissioners are appointed and organized under this act it shall have absolute control of and supervision over the prevention of pollution throughout the said sewerage or drainage district for which the said commissioners were appointed, exclusive of any other body or board in this State now having control of the same: *Provided, however*, That nothing herein contained shall in any way affect or delay or interfere with any action or proceedings which may have heretofore been taken by the State sewerage commission for the purpose of preventing pollution in said sewerage district, or that may hereafter be taken by said State sewerage commission for the enforcement thereof.

11. All acts or parts of acts inconsistent with the provisions of this act be, and the same are hereby, repealed, and this act shall take effect immediately.

Approved March 27, 1902.

[Act passed by the special session of the legislature convened April 21, 1903. Laws of 1903, p. 777.]

AN ACT to relieve from pollution the rivers and streams within the Passaic Valley sewerage district, established and defined by an act of the legislature entitled "An act to create a sewerage district to be called the Passaic Valley sewerage district," approved March twenty-seventh, one thousand nine hundred and two, and for this purpose establishing therefor a district board of commissioners, defining its powers and duties, and providing for the appointment, terms of office, duties, and compensation of such commissioners, and further providing for the raising, collecting, and expenditure of the necessary moneys.

Whereas the legislature of this State has created and defined a sewerage district, embracing a large number of municipalities and parts of municipalities, in the counties of Passaic, Bergen, Hudson, and Essex, under the name of the Passaic Valley sewerage district; and

Whereas the Passaic River and many streams flowing into it within said sewerage district are polluted by sewage and other deleterious matter to the extent that the health of the people residing in said district is seriously endangered; and

Whereas immediate relief therefrom is imperative; and

Whereas the governor of this State, by sanction of the legislature, has appointed five commissioners for said district with power, among other things, to investigate methods and plans for relieving the streams and rivers within said district from pollution, and for preventing the pollution of the same; and

Whereas said commissioners have adopted an effectual plan or method for relieving the streams and rivers within said district from pollution, and for preventing the pollution of the same, and have reported said plan or method to the legislature; and

Whereas in order to carry into effect such plan or method, wit

such modifications or additions thereto as shall hereafter be approved by said commissioners, it is necessary that further and greater power be given to said commissioners:

Be it enacted by the senate and general assembly of the State of New Jersey:

1. The commissioners heretofore appointed by the governor of this State in and for the Passaic Valley sewerage district shall continue in their respective offices for the terms for which they were severally appointed, and said terms are hereby extended to the first Tuesday of May succeeding the date when their terms under said appointments would respectively expire; and hereafter one commissioner shall be appointed by the governor, by and with the advice and consent of the senate, in each year for a term of five years, beginning on the first Tuesday of May next following the date of his appointment. Any vacancy occurring in the office of commissioner by death, resignation, or otherwise shall be filled by the governor, but for the unexpired term only. Each of the said commissioners hereafter appointed, before he enters upon the duties of his office, shall take and subscribe an oath that he will faithfully and impartially execute and perform the duties imposed upon him by law, and cause the same to be filed in the office of the secretary of state of this State. The commissioners shall each receive for services under this act an annual salary of twenty-five hundred dollars, payable in equal monthly installments, and the said commissioners shall henceforth receive no other compensation than that provided under this act. The governor of this State shall have power to remove any commissioner from office for cause during his term of office, and upon removal to fill the vacancy thus occasioned for the unexpired term. In making appointments, either for full terms or to fill vacancies, regard shall be had by the governor both to ability and fitness, and also to locality, so that each section of the district may be represented as far as practicable. No commissioner shall be directly or indirectly interested in any contract awarded under the provisions of this act, nor in furnishing materials or supplies therefor to any contractor, nor in furnishing security for the performance of any contract. If at any time it shall appear to the satisfaction of the governor of this State that any commissioner is or has been so interested, or is or has been a stockholder in any corporation furnishing material or supplies to any contractor for work done or to be done under the provisions of this act, or that he is the owner of any lands or water or water rights taken or to be taken or used in or for the construction of any work under the provisions of this act, or a stockholder in any corporation owning or leasing any such lands or waters or water rights, it shall be the duty of the governor to remove such commissioner from office forthwith, and all contracts made by such sewerage commissioners wherein any such

ommissioner shall have been interested, directly or indirectly, as foresaid, or otherwise, shall thereupon become and be null and void, nd no further payments on account thereof shall be made by said ewerage commissioners.

2. The said commissioners shall, on the first Tuesday in May of ach year, at the hour of two o'clock in the afternoon, organize by he choice of one of their members as chairman of the board, and hey may elect a treasurer, who may or may not be a member of the oard, and a clerk, who may or may not be a member of the board, nd may also from time to time appoint such other officers, attorneys, gents, employees, and servants, and such engineers and assistants as hey may deem necessary to carry out the purposes of this act, and nay prescribe the duties and fix the compensation of all officers, ttorneys, agents, employees, servants, engineers, and assistants; and ll appointees of said commissioners may be removed at their pleasure. The organization of said board and the appointment of officers, gents, clerks, servants, engineers, and assistants heretofore made by the said board shall have the same effect as if made under this act.

3. The said commissioners heretofore appointed and their successors in office are and shall continue to be a body politic and corporate, with perpetual succession under the name of "Passaic Valley sewerage commissioners," with power to sue and be sued, with power to adopt and use a corporate seal, and the right, power, and authority to acquire, hold, use, and dispose of all such property, real and personal, as may be proper or necessary, and with all other powers proper or necessary to carry out and effectuate the purposes for which said board is created.

4. The board of Passaic Valley sewerage commissioners, incorporated as aforesaid, is hereby given full power and authority to make, construct, maintain, and operate intercepting, main, trunk, and outlet sewers with the necessary pipes, conduits, pumping works, and other appliances for the purpose of taking up, within the said Passaic Valley sewerage district, sewage and other offensive and deleterious matter which would or might otherwise pollute the streams and rivers in said district and convey the same to some proper place or places of deposit, discharge, or outfall in the New York Bay, within the State of New Jersey, to be selected by the said sewerage commissioners, there to be discharged, which place or places of deposit, discharge, or outfall shall be at least one and one-quarter miles, measured at right angles, in an easterly direction, from the exterior line for solid filling in the New York Bay, as now established by the riparian commissioners of this State, and in a tidal channel of not less than forty feet in depth at mean low water; and the said sewerage commissioners shall also have power to establish within sai sewerage district, when necessary, sewage disposal works and wor

for the treatment, disinfecting, and disposal of sewage: *Provided, however*, That no sewage disposal work and works for the treatment, disinfecting, and disposal of sewage shall be erected, established, or maintained within the distance of five miles from the outfall of said trunk sewer herein provided for: *Provided, however*, That nothing herein contained shall in any way be construed to allow or permit said sewerage commission to establish or build more than one sewage disposal works or more than one plant or works for the treatment, disinfecting or disposal of sewage; no contract of any kind shall be awarded at any one time for more than one million dollars: *Provided, however*, That this provision shall not apply to the sale of bonds. All work done and materials purchased in the prosecution of said work or works, the cost of which shall exceed five thousand dollars, shall be be by contract awarded, after due advertisement, to the lowest responsible bidder, and all contractors shall be required to give bonds satisfactory in security and amount to the said board; and no contract involving an expenditure of more than twenty-five thousand dollars shall be awarded until after the same shall have been submitted to and approved by the governor: *Provided*, That no contract for any of the work herein required to be performed by contract shall be awarded except on the express stipulation that so far as practicable all said work shall be performed by union labor, and preference shall be given to citizens of the State of New Jersey.

5. It shall be the duty of all persons, corporations, and municipalities owning or controlling the sewers or drains within the limits of said sewerage district, which discharge directly or indirectly into the streams or rivers within the said sewerage district any sewage or deleterious matter, to cause the same to be connected with and to be discharged into the sewers constructed by the said sewerage commissioners when the same shall have been constructed, and at the places which shall have been designated for that purpose by the said sewerage commissioners; all sewers and drains hereafter constructed by any person, corporation, or municipality within the said sewerage district conveying or discharging sewage or other deleterious matter, which might otherwise discharge into or be discharged into the streams or rivers within the said sewerage district, directly or indirectly, shall be so constructed that the outfall or discharge therefrom shall be delivered into the drains or sewers provided by the said sewerage commissioners at the points and places designated by the said commissioners; and it shall be the duty of the said sewerage commissioners, in constructing said intercepting or main sewers, to have them so constructed that connection therewith can be made at necessary or proper points; and all such connections shall be made in accordance with the rules and regulations from time to time adopted by the said sewerage

commissioners in relation thereto, and under the direction and supervision of their officers and agents, and all such connections shall be the property of such sewerage commissioners; the main, intercepting or trunk sewer to be constructed by the said sewerage commissioners shall commence at or near the Valley of Rocks, in the city of Paterson, and shall extend to the point of discharge or outfall in the New York Bay, within the limits of the State of New Jersey; before any moneys expended or obligations are incurred for the construction of any trunk or outlet sewer which shall discharge into New York Bay, the said board shall carefully investigate whether said discharge is likely to pollute the waters of said bay within the jurisdiction of the State of New York to such an extent or in such a degree as to cause a nuisance to persons or property within said State, and shall present the result of their investigation to the governor with their opinion thereon and their reasons for their opinion; and thereupon the same shall be considered by the governor and the attorney-general, and no work shall be done or further proceedings taken unless the attorney-general shall, in writing, advise that no cause of action either for damages or an injunction will arise in favor of the State of New York or any of its inhabitants by reason of such discharge of sewage into the waters of New York Bay, and the governor shall, by order, in writing, advise said board that, in his judgment, it is safe and prudent to proceed with its work, due regard being had to all the risks and dangers of injunctive litigation.

6. The said sewerage commissioners shall have power and authority to purchase and acquire lands and rights or interests in lands within and without the said sewerage district which may be deemed necessary for the construction of sewers, drains, disposal, pumping or other works authorized by this act, but no ventilating plant, sewage disposal works, or works for the treatment, disinfecting, or disposal of sewage shall be erected or maintained outside of said sewerage district; and if in any case the said sewerage commissioners shall be unable to agree with the owner or owners of any lands or rights or interests in lands deemed necessary by said sewerage commissioners in the construction and prosecution of the work hereby authorized, or when by reason of legal incapacity or absence of such owner or owners no agreement can be made for the purchase thereof, the lands or rights or interests in lands so deemed necessary for the purposes of this act shall be acquired by condemnation by the said sewerage commissioners in the manner provided by the general laws of this State relating to the condemnation of lands for public uses: *Provided*, That no private property shall be taken for the purposes of this act without compensation therefor shall have first been made or tendered to the owner or owners thereof, or, in lieu thereof, paid to the clerk of the

county in which the lands taken are located for the use of the person or persons entitled to receive the same; and in case such payment or tender to the owner or owners, or payment into court, is made by the said sewerage commissioners upon the award of commissioners, the said sewerage commissioners shall be entitled to take immediate possession of the property so condemned, notwithstanding any appeal. and the acceptance by the owner or owners of the lands or rights so condemned of any award of commissioners shall not interfere with or prevent the taking of any appeal provided by law.

7. The said board of sewerage commissioners shall have power to construct any sewer or drain by it to be made or constructed under or over any water course, under or over or across or along any street. turnpike, railway, canal, highway, or other way, and in or upon private or public lands, and in or upon lands of this State and under waters of this State, in such manner, however, as not unnecessarily to obstruct or impede travel or navigation, and may enter upon and dig up any street, road, highway, or private or public lands either within or without the said sewerage district for the purpose of constructing or laying sewers or drains upon or beneath the surface thereof, and for maintaining and operating the same, and in general may do all other acts or things necessary, convenient, and proper to carry out the purposes of this act; but no part of said sewer where laid under the waters of this State beyond the exterior lines for solid filling, as established by the riparian commissioners of this State, shall in said Newark Bay be above an elevation of thirty feet below mean low water, or shall in said New York Bay be above an elevation of thirty-five feet below mean low water: and the said board of sewerage commissioners shall have power, for the purpose of carrying such sewage or other matter to the place of deposit or discharge in New York Bay. to construct sewers within territory outside of the said sewerage district, and with its sewers, pipes, and drains to pass through or partly through the territory of municipalities outside of said sewerage district; and whenever the said board shall dig up any road, street, or highway as aforesaid, it shall, as far as possible, restore the same to as good condition and order as the same was when such digging commenced: *Provided, however*, That when such streets, roads, or highways lie outside of such sewerage district, the laying down of sewers or drains under or across said streets, roads, or highways shall be subject to such police regulations of the governing bodies of such municipalities as are applicable and enforceable in the construction of sewers or drains for such municipality.

8. The said sewerage commissioners shall have power and authority to alter or change the course or direction of any water course, and. with the consent of the township committee of any township and of the board or body having control of the streets or highways in any

city, town, or other municipality, to alter or change the grade or location of any highway, public street, or way crossed by any sewer or drain to be constructed under the provisions of this act.

9. The said board of sewerage commissioners may, by its officers, agents, servants, and employees, enter at all times upon any lands or waters within or without the said sewerage district for the purpose of exploring, surveying, leveling, and laying out the route of any drain or sewer, locating any disposal, pumping, or other works, establishing grades, and doing all necessary preliminary work; doing, however, no unnecessary damage or injury to private property.

10. The said board of sewerage commissioners shall at all times keep full and accurate accounts of its receipts, expenditures, disbursements, and liabilities, and shall annually cause a detailed statement thereof to be published and a copy thereof mailed to the secretary of state of this State and to the clerk of each of the municipalities in the district. The fiscal year of said sewerage commissioners shall end on the first Tuesday of May in each year, and said report so to be published shall be a report for the previous fiscal year, and shall be made as soon after the end of each fiscal year as conveniently may be; and the mayor or chief officer of any city or other municipality included within said drainage district shall be given full access to all the books, accounts, and vouchers of the said board, at all reasonable times, for the purpose of examination and report in the interest of such municipalities, respectively, and of the taxpayers therein.

11. To provide for the payment of costs and expenses incurred or to be incurred by the said sewerage commissioners for the purchase of lands, rights, or interests in lands or other property or rights, and in the construction of said disposal works, pumping stations, sewers, drains, and all other works by them to be constructed, and for engineering, administrative, and other expenses connected therewith, including interest during construction, said board of sewerage commissioners shall have power from time to time to issue its corporate bonds in an amount not to exceed nine million dollars and not to exceed the total estimated cost and expenses of the whole work; such bonds shall be in the form and payable at a time not exceeding fifty years from the date thereof and at such places, and either in currency or coin, as the said sewerage commissioners may determine; such bonds shall bear interest at a rate not exceeding four per centum per annum, payable semiannually; all such bonds shall be signed by the chairman of the said board of sewerage commissioners and countersigned by the treasurer, and shall be sealed with its corporate seal, attested by the clerk; in issuing such bonds the board of sewerage commissioners may, in its discretion, make the same or any part thereof fall due at stated periods less than fifty years from the da of issue, and may reserve in said bonds an option to redeem or pa

county in which the lands taken are located for the use of the person or persons entitled to receive the same; and in case such payment or tender to the owner or owners, or payment into court, is made by the said sewerage commissioners upon the award of commissioners, the said sewerage commissioners shall be entitled to take immediate possession of the property so condemned, notwithstanding any appeal, and the acceptance by the owner or owners of the lands or rights so condemned of any award of commissioners shall not interfere with or prevent the taking of any appeal provided by law.

7. The said board of sewerage commissioners shall have power to construct any sewer or drain by it to be made or constructed under or over any water course, under or over or across or along any street, turnpike, railway, canal, highway, or other way, and in or upon private or public lands, and in or upon lands of this State and under waters of this State, in such manner, however, as not unnecessarily to obstruct or impede travel or navigation, and may enter upon and dig up any street, road, highway, or private or public lands either within or without the said sewerage district for the purpose of constructing or laying sewers or drains upon or beneath the surface thereof, and for maintaining and operating the same, and in general may do all other acts or things necessary, convenient, and proper to carry out the purposes of this act; but no part of said sewer where laid under the waters of this State beyond the exterior lines for solid filling, as established by the riparian commissioners of this State, shall in said Newark Bay be above an elevation of thirty feet below mean low water, or shall in said New York Bay be above an elevation of thirty-five feet below mean low water; and the said board of sewerage commissioners shall have power, for the purpose of carrying such sewage or other matter to the place of deposit or discharge in New York Bay, to construct sewers within territory outside of the said sewerage district, and with its sewers, pipes, and drains to pass through or partly through the territory of municipalities outside of said sewerage district; and whenever the said board shall dig up any road, street, or highway as aforesaid, it shall, as far as possible, restore the same to as good condition and order as the same was when such digging commenced: *Provided, however*, That when such streets, roads, or highways lie outside of such sewerage district, the laying down of sewers or drains under or across said streets, roads, or highways shall be subject to such police regulations of the governing bodies of such municipalities as are applicable and enforceable in the construction of sewers or drains for such municipality.

8. The said sewerage commissioners shall have power and authority to alter or change the course or direction of any water course, and, with the consent of the township committee of any township and of the board or body having control of the streets or highways in any

.ty, town, or other municipality, to alter or change the grade or loca-
on of any highway, public street, or way crossed by any sewer or
rain to be constructed under the provisions of this act.

9. The said board of sewerage commissioners may, by its officers,
gents, servants, and employees, enter at all times upon any lands or
·aters within or without the said sewerage district for the purpose of
xploring, surveying, leveling, and laying out the route of any drain
r sewer, locating any disposal, pumping, or other works, establishing
rades, and doing all necessary preliminary work; doing, however, no
nnecessary damage or injury to private property.

10. The said board of sewerage commissioners shall at all times
eep full and accurate accounts of its receipts, expenditures, disburse-
ıents, and liabilities, and shall annually cause a detailed statement
hereof to be published and a copy thereof mailed to the secretary of
tate of this State and to the clerk of each of the municipalities in the
istrict. The fiscal year of said sewerage commissioners shall end on
he first Tuesday of May in each year, and said report so to be pub-
ished shall be a report for the previous fiscal year, and shall be made
s soon after the end of each fiscal year as conveniently may be; and
he mayor or chief officer of any city or other municipality included
vithin said drainage district shall be given full access to all the
ooks, accounts, and vouchers of the said board, at all reasonable
imes, for the purpose of examination and report in the interest of
uch municipalities, respectively, and of the taxpayers therein.

11. To provide for the payment of costs and expenses incurred or
o be incurred by the said sewerage commissioners for the purchase
f lands, rights, or interests in lands or other property or rights, and
n the construction of said disposal works, pumping stations, sewers,
rains, and all other works by them to be constructed, and for engi-
eering, administrative, and other expenses connected therewith,
ncluding interest during construction, said board of sewerage com-
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hereof fall due at stated periods less than fifty years from the dat
f issue, and may reserve in said bonds an option to redeem or pa

the same or any part thereof at stated periods at any time between the date thereof and the date at which they would otherwise fall due; the said bonds may be either coupon or registered bonds or partly coupon and partly registered bonds, and all such bonds may be negotiated, sold, and disposed of at not less than their par value, and the same or the proceeds thereof may be used by the said sewerage commissioners for the purposes aforesaid; the said board of sewerage commissioners shall keep the cost and expenses of the construction of its plant—in which shall be included the cost of lands, rights, or interests in lands, and the cost of all other property and rights, and the cost of construction of all works, including engineering expenses, administrative expenses, and legal expenses, and including interest during the course of construction—separate from the cost and expenses of maintenance, operation, and repairs; all sales of bonds shall be made after public notice and advertisement calling for bids and shall be made to the highest responsible bidders.

12. The said board of sewerage commissioners may, in anticipation of the issuing of bonds, and from time to time as it may need money, borrow such sum or sums of money, not exceeding at any one time one-fifth of the estimated cost of the whole work, and may issue its certificates of indebtedness, promissory notes, or other obligations therefor, retiring the same from time to time as the bonds hereinbefore authorized to be issued are sold. In order that the said bonds issued for the purchase of land, rights in land, and for the construction of the works, plant and extensions, betterments and improvements thereof may be paid and retired at maturity, the sewerage commissioners shall provide a proper and suitable sinking fund not exceeding in amount to be raised in any one year one per centum of the face value of the bonds issued, which sum shall be raised annually, beginning with the fifth year after the issuing of said bonds, at the time and in the manner herein provided for the raising of the moneys necessary to pay the interest on said bonds. The money so raised for sinking-fund purposes shall be kept in a separate account by the treasurer of the board of sewerage commissioners, and shall, under its direction, be used or invested from time to time in the purchase or retirement of its own bonds, or in the purchase of securities in which savings banks and savings institutions of this State are authorized to invest.

13. All indebtedness of the said board of sewerage commissioners incurred for the purchase of lands, rights, or interests in land or other property, and in the construction of its works or plant, or otherwise lawfully incurred, pursuant to the provisions of this act, whether such indebtedness is represented by bonds, certificates of indebtedness, promissory notes, or other form of indebtedness, with interest accrued or to accrue thereon, shall be a charge upon all per-

ns and property in the municipal or taxing districts lying in whole in part within said sewerage district as fully as the legislature of is State shall have power to authorize the same; and all bonds, rtificates of indebtedness, promissory notes, and other obligations sued by the said board of sewerage commissioners shall be free om all State, county, municipal, and other taxes, and the property, al and personal, of the said board of sewerage commissioners held it under authority of this act, wherever situated, shall in like manr be free from taxation.

14. The said sewerage commissioners shall, on or before the fifenth day of June in each year, ascertain and determine the amount money necessary to be raised for the payment of interest upon nds and other indebtedness and for sinking-fund charges for the rrent fiscal year, and shall apportion the same among the respective unicipalities and taxing districts lying in whole or in part within id sewerage district, in such proportion as the taxable ratables ithin so much of said municipality or taxing district as is embraced ithin said sewerage district bears to the total amount of taxable tables within the whole of said sewerage district, as returned and rtified by the respective taxing boards and taxing officers of the id municipalities or taxing districts for the preceding year: *Proded, however*, That all ratables in said district for this purpose be sessed at their true value; and it shall be the duty of each assessor, xing board, or taxing officer for the several municipalities and taxg districts lying in whole or in part within said sewerage district r this purpose, to examine, compute, determine, and certify to the id sewerage board annually, and by the first day of April of each ar, the amount of taxable property or ratables assessed in the last receding year to or upon persons and property within so much of e several municipalities and taxing districts as lie within the said werage district, and the books of each of the said assessors, taxing ards, and taxing officers shall at all times be open for examination the board of sewerage commissioners, its officers and agents, for e purpose of examining, checking, and, if necessary, correcting id certificates.

15. The said board of sewerage commissioners shall, on or before e fifteenth day of June in each year, ascertain and determine as ar as may be the amount of money necessary to be raised for opering, maintaining, and repairing its works and plant for the current cal year, and shall apportion the money so estimated to be necesry among the several municipalities or taxing districts lying in hole or in part within said sewerage district according to the nount of sewage by them respectively delivered to or discharge to any sewers or other receptacles provided or constructed by id sewerage commissioners for the reception thereof. Before s portionment is finally made and adopted by the sewerage com

sioners for any year and on the fourth Tuesday of May, at two o'clock in the afternoon, the said sewerage commission shall sit at its principal office for the purpose of hearing such municipalities as desire to be heard upon the apportionment of the estimated amount of money required for the operation, maintenance, and repair of said works and plant, but the apportionment when made by the said sewerage commissioners shall be final and conclusive; in case, however, the estimate of moneys necessary to be raised in any year for operating, maintaining, and repairing the works and plant of the sewerage commissioners shall, at the end of the year, be found to have been too low, the deficiency shall be made good by adding the same to the estimated amount required for operating, maintaining, and repairing the said works for the next succeeding year; and if said estimate shall be found to have been excessive, then such excess shall be deducted from the estimate for the next succeeding year.

16. The said board of sewerage commissioners shall, on or before the twentieth day of June in each year, order and cause a tax to be levied and assessed upon all persons and property within each of the municipal and taxing districts lying in whole or in part within said sewerage district, for the purpose of raising the money necessary to pay interest upon its bonds and other indebtedness and necessary sinking-fund charges and for the sum or sums of money estimated as necessary to provide for the proper maintenance and operation of its works and plant, and for all the other expenses of the said sewerage commissioners, and to this end it shall, on or before the twentieth day of June in each year, certify to the tax assessor, taxing board, or taxing officer of each of said municipalities or taxing districts lying in whole or in part within said sewerage district, the amount of tax required to be levied, assessed, and raised in each of their respective municipalities and taxing districts for said purposes; and the said assessors, taxing boards, and taxing officers shall assess said sums so directed to be assessed (and certified to them) upon all the persons and property within their respective municipalities or taxing districts liable to be assessed for State or county taxes, and the said tax shall be levied, assessed, and collected by the same officers at the same time and in the same manner and with the same effect as State or county taxes are required to be levied, assessed, and collected within said municipalities or taxing districts; and the taxes so levied upon real estate in said municipalities and taxing districts shall be and remain a first and paramount lien thereon until paid.

17. Out of the first moneys collected in any year in any municipality or taxing district, and not required by law to be paid to the county collector for State or county purposes, it shall be the duty of the disbursing officer or officers of such municipality or taxing dis-

ict to pay to the treasurer of the sewerage commissioners the sum · sums of money directed by said sewerage commissioners to be sessed, levied, and collected in such municipality or taxing district.

18. The said board of sewerage commissioners may, from time to me, in anticipation of the collection of moneys directed by it to be sessed, levied, and collected within the municipalities or taxing stricts lying in whole or in part within its sewerage district, borrow ich sum or sums of money as may be necessary for the payment of terest upon bonds or other indebtedness, and for the payment of nking-fund charges, and for the payment of its officers, agents, nployees, and for all other necessary or proper expenses in maining and operating its works and plant, and the payment of the oneys so borrowed shall be secured by a lien upon said taxes as vied and assessed, or so directed to be levied and assessed, and said xes when collected shall be applied to the payment of the moneys borrowed; all loans made in pursuance of this section shall be fter public notice and advertisement, and shall be made or taken om the person or persons offering the most favorable terms.

19. If in any case the streams and rivers within the said sewerage istrict are or may be polluted by sewage or other deleterious matter ischarged therein, directly or indirectly, from any municipality or ny part of a municipality lying without the said sewerage district, it all and may be lawful for the said board of commissioners to enter ito contract with such municipality for the disposal of all such sewge and deleterious matter, and every such municipality is hereby uthorized to enter into such contract with the said board, and the aid board may, in the constructions made by it under the authority f this act, make provisions for such disposal; such contracts may be ade upon such terms and for such lengths of time and for such nnual or semiannual payments as shall be mutually agreed upon, nd the municipalities and taxing districts so contracting shall have he power to raise annually, by taxation, the moneys necessary to ake the payments required to be made under such contracts, or to se for this purpose any moneys not otherwise appropriated; and the oneys received by the said commissioners under such contracts shall e applied by them as follows: Two-thirds thereof to the payment of nterest upon bonds issued by the said board, and one-third thereof o the payment of the expense of operation, maintenance, and repair f work.

20. The said sewerage commissioners shall have within said sewerge district powers exclusive of all other boards to protect the rivers nd streams thereof from pollution and to prevent the pollution of he same, and to this end the said sewerage commissioners may proibit the deposit or discharge into the rivers or streams within said ewerage district of any sewage or other matter or thing which may

pollute the same; they may also in like manner prohibit or prevent the emptying into any tributary of said rivers or streams, by any municipality or part of a municipality lying within the said sewerage district, of any sewage or other matter or thing which will directly or indirectly cause the rivers or streams within said sewerage district to be polluted; and the said board of sewerage commissioners may at any time, when it has reason to believe that any river or stream within its district is being polluted by any such municipality or part of a municipality by deposit or discharge into said rivers, streams, or their tributaries of any sewage or other matter or thing which will pollute the same, or when such deposit or discharge is threatened, to apply by bill or petition to the court of chancery of this State for injunction to prevent the said pollution or threatened pollution of said rivers or streams or their tributaries, and the court of chancery shall have power to hear and dispose of said petition or bills in a summary manner, and to grant any and all relief necessary to prevent said pollution or threatened pollution or the continuation of any pollution of said rivers, streams, or their tributaries.

21. The said board of sewerage commissioners shall have power from time to time to adopt all such reasonable rules and regulations for its own government and the government of its officers and agents, and also for the use, protection, and management of its works, property, and plant, and for the protection of the rivers and streams within its district from pollution, not inconsistent with the provisions of this act and the laws of this State.

22. The chairman shall preside at all meetings of the sewerage commissioners, and shall, with the treasurer, sign all bonds, promissory notes, certificates of indebtedness, and other obligations of the board; he shall also countersign all checks; in the absence of the chairman, or in case he is incapacitated by illness or other cause, the sewerage commissioners shall have power to elect an acting chairman, who for the time being shall have all the powers and perform all the duties of the chairman; the treasurer shall give bond in such sum as the sewerage commissioners may determine, and shall be the receiving and disbursing officer of the said sewerage commissioners, and all moneys required by law to be paid to said sewerage commissioners shall be paid to the treasurer thereof, and shall be by him deposited in such bank or banks of deposit or trust company or trust companies in this State as shall be determined upon by the said sewerage commissioners; all disbursements shall be by check, signed by the treasurer and countersigned by the chairman; the clerk shall have charge of the seal of the corporation and shall affix it to such instruments as he shall be directed by the said board, and he shall attest the same; he shall keep full minutes of all the meetings of the board and of its committees and shall perform all such other duties

as he may be directed by the said board of commissioners to perform; no deposit of moneys in the charge of the said board shall be made in any bank or trust company except upon the condition that the said board shall receive interest at the rate of not less than two per centum per annum upon the said deposits.

23. In case for any reason any section or any provision of this act shall be questioned in any court and shall be held to be unconstitutional or invalid, the same shall not be held to affect any other section or provision of this act.

24. All acts and parts of acts inconsistent with this act are hereby repealed; and this act shall take effect immediately.[a]

Approved April 22, 1903.

NEW YORK.

[Revised Statutes, 3d ed. (C. F. Birdseye), vol. 2, pp. 2822 ff., Article V: Public health law.]

POTABLE WATERS.

SEC. 70. *Rules and regulations of State board.*—The State board of health may make rules and regulations for the protection from contamination of any or all public supplies of potable waters and

[a] This act was declared unconstitutional by the court of errors and appeals of New Jersey in March, 1905. Van Cleve v. Passaic Valley Sewerage Commissioners, 60 Atlantic Rep., 214. It is retained here, however, because the ground upon which it was held unconstitutional affects only the mode of raising the necessary funds for carrying out the work.

It was subjected to an attack by the city of Paterson and by a property owner who had been assessed for public sewers in the city of Paterson. Argument was conducted by several of the ablest counsel in the State on each side and the act was sustained upon all grounds in the supreme court, but by a divided court. In the court of errors and appeals the action of the supreme court was reversed, and the act declared to be unconstitutional upon the ground that it contained an unlawful delegation to the sewerage commissioners of the power of taxation. The court says, per Garrison, J., "To relieve a river from pollution and to construct and maintain for this purpose sewers to the seaboard or to other point of output and to carry away through such sewers all that would otherwise pollute such river is clearly within the power of the central legislative body."

The act under examination authorized the commissioners to raise by taxation any amount in their discretion, subject only to the limit of nine million dollars ($9,000,000) in the matter of construction, but without any limit in the matter of maintenance. The taxation was laid upon a taxation area that was not coterminous with the sewerage district established by the legislature; and neither the taxation area nor the sewerage district is a political division of the State nor invested with any governmental function. The court held that the fundamental law of New Jersey required, "that the district to be taxed shall be coterminous with a district to which some right of local self-government is given." The act is, therefore, held invalid. The court then proceeds as follows: "Having stated the considerations that lead me to the conclusion that the act before us is invalid, because of its fiscal provision, I shall, to avoid misapprehension, add that nothing in this opinion is intended to imply a lack of power in the legislature to effectuate the object expressed in this act by means that are in harmony with the fundamental principles of taxation illustrated by the decisions I have cited. If, for instance, as was suggested by the arguments before us, powers adequate to the execution of the legislative scheme of drainage were conferred upon the entire area to be taxed and duties respecting the exercise of such powers constitutionally imposed in such manner indicated and that their exercise was compulsory, a question not touched upon in th opinion would be presented."

their sources within the State. If any such rule or regulation relates to a temporary source or act of contamination, any person violating such rule or regulation shall be liable to prosecution for misdemeanor for every such violation, and on conviction shall be punished by a fine not exceeding two hundred dollars, or imprisonment not exceeding one year, or both. If any such rule or regulation relates to a permanent source or act of contamination, said board may impose penalties for the violation thereof or the noncompliance therewith not exceeding two hundred dollars for every such violation or noncompliance. Every such rule or regulation shall be published at least once in each week for six consecutive weeks in at least one newspaper of the county where the waters to which it relates are located. The cost of such publication shall be paid by the corporation or municipality benefited by the protection of the water supply to which the rule or regulation published relates. The affidavit of the printer, publisher, or proprietor of the newspaper in which such rule or regulation is published may be filed with the rule or regulation published in the county clerk's office of such county, and such affidavit and rule and regulation shall be conclusive evidence of such publication and of all the facts therein stated in all courts and places.

SEC. 71. *Inspection of water supply.*—The officer or board having by law the management and control of the potable water supply of any municipality, or the corporation furnishing such supply, may make such inspection of the sources of such water supply as such officer, board, or corporation deems it advisable, and to ascertain whether the rules or regulations of the State board are complied with. If any such inspection discloses a violation of any such rule or regulation relating to a permanent source or act of contamination, such officer, board, or corporation shall cause a copy of the rule or regulation violated to be served upon the person violating the same with a notice of such violation. If the person served does not immediately comply with the rule or regulation violated, such officer, board, or corporation shall notify the State board of the violation, which shall immediately examine into such violation, and if such person is found by the State board to have actually violated such rule or regulation, the secretary of the State board shall order the local board of health of such municipality to convene and enforce obedience to such rule or regulation. If the local board fails to enforce such order within ten days after its receipt, the corporation furnishing such water supply, or the municipality deriving its water supply from the waters to which such rule or regulation relates, may maintain an action in a court of record, which shall be tried in the county where the cause of action arose against such person, for the recovery of the penalties incurred by such violation, and for an injunction restraining him from the continued violation of such rule or regulation.

SEC. 71a. *Rules and regulations legalized.*—All rules and regulations heretofore duly made and published for the sanitary protection of public water supplies, pursuant to chap. 543 of the laws of 1885 and chap. 661 of the laws of 1893, as amended, are hereby legalized, ratified, confirmed, and continued in force until new rules and regulations become operative.

SEC. 71b. *Construction of act.*—This act shall not be construed to repeal or affect any of the provisions of chap. 378 of laws of 1897, or its amendments.

SEC. 72. *Sewerage.*—When the State board of health shall, for the protection of a water supply from contamination, make orders or regulations the execution of which will require or make necessary the construction and maintenance of any system of sewerage, or a change thereof, in or for any village or hamlet, whether incorporated or unincorporated, or the execution of which will require the providing of some public means of removal or purification of sewage, the municipality or corporation owning the waterworks benefited thereby shall, at its own expense, construct and maintain such system of sewerage, or change thereof, and provide such means of removal and purification of sewage and such works or means of sewage disposal as shall be approved by the State board of health. When the execution of any such regulations of the State board of health will occasion or require the removal of any building or buildings the municipality or corporation owning the waterworks benefited thereby shall, at its own expense, remove such buildings and pay to the owner thereof all the damages occasioned by such removal.

When the execution of any such regulation will injuriously affect any manufacturing or industrial enterprise which is not a public nuisance, such municipality or corporation shall pay all damages occasioned by the enforcement thereof. Until such construction or change of such system or systems of sewerage, and the providing of such means of removal or purification of sewage, and such works or means or sewage disposal and the removal of any building, are so made by the municipality or corporation owning the waterworks to be benefited thereby at its own expense there shall be no action or proceeding taken by such municipality or corporation against any person or corporation for the violation of any regulation of the State board of health under this article, and no person or corporation shall be considered to have violated or refused to obey any such rule or regulation. The owner of any building the removal of which is occasioned or required, or which has been removed by any rule or regulation of the State board of health made under the provisions of this article, and all persons whose rights of property are injuriously affected by the enforcement of any such rule or regulation, shall have a cause of action against the municipality or corporation owning tl

waterworks benefited by the enforcement of such rule or regulation for all damages occasioned or sustained by such removal or enforcement, and an action therefor may be brought against such municipality or corporation in any court of record in the county in which the premises or property affected is situated and shall be tried therein; or such damages may be determined by a special proceeding in the supreme court or the county court of the county in which the property is situated. Such special proceedings shall be commenced by petition and notice to be served by such owner upon the municipality or corporation in the same manner as for the commencement of condemnation proceedings. Such municipality or corporation may make and serve an answer to such petition as in condemnation proceedings. The petition and answer shall set forth the claims of the respective parties, and the provisions of the condemnation law shall be applicable to the subsequent proceedings upon the petition and answer, if any. Either party may, before the service of the petition or answer, respectively, offer to take or pay a certain sum, and no costs shall be awarded against either party unless the judgment is more unfavorable to him than his offer.

SEC. 72a. *Actions by municipalities.*—Any incorporated city or village in the State of New York which has made such provision for the disposal of its sewage as not to pollute or contaminate therewith any river, stream, lake, or other body of water may have and maintain an action in the supreme court to prevent the discharge of any sewage or substance deleterious to health, or which shall injure the potable qualities of the water in any river, stream, lake, or other body of water from which such incorporated city or village shall take or receive its water supply; provided, that such river, stream, lake, or other body of water is wholly or in part within the boundaries of the county in which such plaintiff is located.

SEC. 72b. *Duty of supreme court.*—Whenever such action shall be brought under the provisions of this act, it shall be the duty of the supreme court, upon proof of the existence of facts justifying the bringing and maintenance of such action under the provisions of this act, to render a judgment in which shall be incorporated a mandatory injunction requiring the person, body, board, corporation, municipality, village, county, or town being a defendant to said action which directly or indirectly, or by its servants, agents, or officers, shall discharge or dispose of its sewage or any other substance deleterious to health, which shall injure the potable qualities of the water in such wise as that the same shall enter into any river, stream, lake, or other body of water from which such plaintiff shall take or receive its water supply, within such reasonable time as may be prescribed by the court, to take such action as shall prevent such discharge, or the dis-

posal of such sewage or other substance into such waters, or the pollution thereof, with such further directions in the premises as may be proper and desirable to effect such purpose; provided, that such river, stream, lake, or other body of water is wholly or in part within the boundaries of the county in which such plaintiff is located.

SEC. 72c. *Examination by State board of health.*—But no such action shall be brought as provided for in section 2 (i. e., 72b) of this act until the State board of health has examined and determined whether the sewage does pollute or contaminate the river, stream, lake, or other body of water into which said sewage is discharged. The expense of such examination by said board shall be a charge upon and paid by the municipality in whose interest and on whose behalf such examination is made.

SEC. 72d. *Approval of plans.*—In case the State board of health shall find upon examination that the discharge of said sewage does pollute or contaminate said waters, or any of them, in such manner as to be of menace or danger to the health of those using said waters, the plans for the removal or disposal of the sewage ordered to be prepared by the court as provided in section 2 (i. e., 72b) shall be submitted to the State board of health for its approval.

[Laws of 1901, vol. 3, p. 214, charter of New York City.]

SEC. 481. It shall not be lawful for any person to throw or deposit, or cause to be thrown or deposited, in any lake, pond, or stream, or in any aqueduct from or through which any part of the water supply of the city of New York shall be drawn, or either of the reservoirs, any dead animal or other offensive matter or anything whatever. Any person offending against the provisions of this section shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be punished by fine or imprisonment, or both, in the discretion of the court, such fine not to exceed the sum of one hundred dollars and such imprisonment not to exceed a period of three months, such imprisonment to be in the jail of the county in which the offense shall have been committed.

SEC. 482. If any person shall willfully do or cause to be done any act whereby any work, materials, or property whatever, erected or used, or hereafter to be erected or used, within the city or elsewhere by the said city, or by any person acting under their authority, for the purpose of procuring or keeping a supply of water, shall in any manner be injured, or shall erect or place any nuisance on the banks of any river, lake, or stream from which the water supply of said city shall be drawn, or shall throw anything into the aqueduct or into any reservoir, or pipe, such person on conviction thereof shall be deemed guilty of a misdemeanor.

Section 483 authorizes the commissioner of water supply, gas, and electricity to carry out the provisions of this act and to prevent contamination.

Section 484 authorizes proceedings to acquire title of lands necessary for this purpose.

By laws of 1893, chapter 661, section 73, the discharge of sewage or other matter deleterious to public health or destructive to fish into Wallkill Creek, in the counties of Ulster and Orange, is prohibited, and section 74 of the same act contains a similar protection for the Susquehanna River or any of its tributaries between the Rock Bottom dam in such river at the city of Binghamton and a point one mile east of the bridge that crosses such river at Conklin.

Law of 1893 was amended by an act passed in 1903, adding the following sections:

[Laws of 1903, chap. 468; became a law May 7, 1903, with the approval of the governor; passed, a majority being present.]

AN ACT to amend the public health law relative to the discharge of sewage and other refuse or waste matter into the waters of this State.

The people of the State of New York, represented in senate and assembly, do enact as follows:

SEC. 1. *Public health law amended.*—Article 5 of chapter 661 of the laws of 1893, entitled "An act in relation to the public health, constituting chapter 25 of the general laws," as amended by chapter 251 of the laws of 1899, is hereby amended by adding at the end thereof the following new sections:

SEC. 75. *Discharge of sewage and other refuse matter in certain waters prohibited.*—No person, corporation, or municipality shall place or cause to be placed, or discharged or cause to be discharged, into any of the waters of this State, unless the same shall have been permitted by the State commissioner of health, any sewage, garbage, offal, dead animal, dead fish, dead bird or part thereof, or any decomposable or putrescible matter of any kind, or any substance, chemical or otherwise, containing the same in quantities injurious to the public health, or any refuse or waste matter, either solid or liquid, in quantities injurious to the public health, from any shop, factory, mill, or industrial establishment, unless express permission to do so shall have been first given in writing by the State commissioner of health, as provided in this article, except as hereinafter provided. But this act shall not prevent the discharge of sewage from any public sewer system owned and maintained by a municipality, or the discharge of refuse or waste matter from any shop, factory, mill, or industrial establishment, provided such sewer system was in operation and was discharging sewage, or such shop, factory, mill, or industrial establishment was in operation and discharging refuse or waste matter,

into any of the waters of this State at or prior to the time of the passage of this act, nor to any extension or modification of such shop, factory, mill, or industrial establishment, or reconstruction thereof, provided the refuse or waste matter discharged therefrom is not materially changed or increased; but this exception shall not permit any increase in the discharge of such sewage, nor shall it permit the discharge of sewage from a sewer system which shall be extended, modified, or reconstructed subsequent to the passage of this act.

SEC. 76. *Permission to discharge sewage.*—Upon application duly made to the State commissioner of health by the public authorities having by law the charge of the sewer system of any municipality, the State commissioner of health shall have power to consider the case of a sewer system otherwise prohibited by this act from discharging sewage into any of the waters of the State, and whenever in his opinion the general interests of the public health would be subserved thereby he may issue a permit for the discharge of sewage from any such sewer system into any of the waters of the State, and may stipulate in the permit modifications, regulations, and conditions on which such discharge may be permitted. Such permit before being operative shall be recorded in the county clerk's office of the county wherein the outlet of the said sewer system is located, and a copy of the permit shall be transmitted by the State commissioner of health to the board of health of the municipality wherein the outlet of said sewer system is located.

SEC. 77. *Permission to discharge refuse or waste matter from industrial establishments.*—Upon application duly made to the State commissioner of health by the proprietor, lessee, or tenant of any shop, factory, mill, or industrial establishment from which the discharge or refuse or waste matter into any of the waters of the State is otherwise prohibited by this act, the State commissioner of health shall have power to consider the case of the said shop, factory, mill, or industrial establishment, and whenever the public health and purity of the waters shall warrant it he shall issue a permit for the discharge of refuse or waste matter from such shop, factory, mill, or industrial establishment into any of the waters of the State, and may stipulate in the permit such modifications, regulations, and conditions as the public health may require. Such permit, before being operative, shall be recorded in the county clerk's office of the county where such shop, factory, mill, or industrial establishment is located, and a copy of such permit shall be transmitted by the State commissioner of health to the board of health of the municipality wherein the outlet discharging refuse or waste matter from such shop, factory, mill, or industrial establishment shall be located.

SEC. 77a. *Plans to be submitted.*—Before any conduit or discharge pipe or other means of discharging or casting any refuse or wast

matter from any shop, factory, mill, or industrial establishment not constructed or in process of construction when this act takes effect shall be put in or constructed for the purpose of discharging any refuse or waste matter therefrom into any waters in this State, the plan or plans therefor, together with a statement of the purpose for which the same is to be used, shall be submitted to the commissioner. If the same is not detrimental to the public health he shall issue a permit therefor to the applicant. No such conduit, discharge pipe, or other means of discharging or casting any refuse or waste matter from any such shop, factory, mill, or establishment into any of the waters of this State shall be put in or constructed before such permit is granted, and if put in or constructed the person putting in or constructing or maintaining the same shall forfeit to the people of the State five dollars a day for each day the same is used or maintained for such purpose, to be collected in an action brought by the commissioner. He may also maintain an action in the name of the people to restrain a violation of this section.

SEC. 78. *Revocation of permit.*—Every such permit for the discharge of sewage from a sewer system or for the discharge of refuse or waste matter from a shop, factory, mill, or industrial establishment shall, when necessary to conserve the public health, be revocable or subject to modification or change by the State commissioner of health on due notice after an investigation and hearing and an opportunity for all interested therein to be heard thereon being served on the public authorities of the municipality owning and maintaining the sewage system, or on the proprietor, lessee, or tenant of the shop, factory, mill, or industrial establishment. The length of the time after receipt of the notice within which the discharge of sewage or of refuse or waste matter shall be discontinued may be stated in the permit, but in no case shall it exceed two years in the case of a sewer system nor one year in the case of a shop, factory, mill, or industrial establishment, and if the length of time is not specified in the permit it shall be one year in the case of a sewer system and six months in the case of a shop, factory, mill, or industrial establishment. On the expiration of the period of time prescribed after the service of a notice of revocation, modification, or change from the State commissioner of health, the right to discharge sewage or refuse or waste matter into any of the waters of the State shall cease and terminate, and the prohibition of this act against such discharge shall be in full force as though no permit had been granted, but a new permit may thereafter again be granted as hereinbefore provided.

SEC. 79. *Reports of municipal authorities to local boards of health.*—It shall be the duty of the public authorities having by law charge of the sewer system of every municipality in the State, from which sewer

system sewage was being discharged into any of the waters of the State at the time of the passage of this act, to file with the board of health of the municipality within which any sewer outlet of the said sewer system is located and within sixty days after the passage of this act a report of each sewer system having an outlet within the municipality, which report shall comprise such facts and information as the State commissioner of health may require and on blanks or forms to be furnished by him on application. The board of health of each municipality being satisfied as to the correctness and completeness of each report submitted to it shall within thirty days after its receipt certify the same and transmit it to the State commissioner of health. Such report when satisfactory to the State commissioner of health shall be filed by him in his office and shall constitute the evidence of exemption from the prohibition of this act. No sewer system shall be exempt from the prohibition of this act against the discharge of sewage into the waters of the State for which a satisfactory report shall not be filed in the office of the State commissioner of health in accordance with this section.

SEC. 79a. *Reports of proprietors of industrial establishments.*—It shall be the duty of the proprietor of every shop, factory, mill, and industrial establishment in the State from which refuse or waste matter was being discharged into any of the waters of the State at the time of the passage of this act to file with the State commissioner of health within sixty days after the passage of this act a report of each shop, factory, mill, and industrial establishment from which refuse or waste matter was being discharged through an outlet within the municipality at the time of the passage of this act, which report shall comprise such facts and information in regard to the size, location, and character of shop, factory, mill, or industrial establishment, the machinery in use therein, and the character and quantity of goods produced as the State commissioner of health may require and on blanks or forms to be furnished by him on application. Such report shall be filed by him in his office, and shall constitute the evidence of exemption of the shop, factory, mill, or industrial establishment from the prohibition of this act. No shop, factory, mill, or industrial establishment shall be exempt from the prohibition of this act against the discharge of refuse or waste matter into the waters of the State, for which a report shall not be made as required by the State commissioner of health in accordance with this section.

SEC. 79b. *Record of permits; inspection of local boards of health.*—Each board of health shall preserve in its office, and in a form to be prescribed by the State commissioner of health, a permanent record of each permit issued by the State commissioner of health granting

the right to discharge sewage or refuse or waste matter into any of the waters of the State within that municipality and of each revocation of a permit; and also a permanent record of each report received by the board of health concerning each sewer system and each shop, factory, mill, or industrial establishment which at the time of the passage of this act was discharging sewage or refuse or waste matter into any of the waters of the State within that municipality. Each local board of health shall make and maintain such inspection as will at all times enable it to determine whether this act is being complied with in respect to the discharge of sewage, refuse, or waste matter or other materials prohibited by this act into any of the waters of the State within that municipality. For the purpose of such inspection every member of such board of health, or its health officers, or any person duly authorized by it, shall have the right to make all necessary examinations of any premises, building, shop, factory, mill, industrial establishment, process, or sewage system.

SEC. 79c. *Violations; service of notice; actions by local boards.*—The local board of health of each municipality shall promptly ascertain every violation of or noncompliance with any of the provisions of this act or of the permits for the discharge of sewage or refuse or waste material into any of the waters of the State herein provided which may occur within that municipality. The board of health shall, on the discovery of every violation of or noncompliance with any of the provisions of this act or of any permit duly issued, serve a written notice on the person or corporation responsible for the violation or noncompliance, together with a copy of this act and of the permit, if any, violated or noncomplied with, specifying the particular provision being violated or noncomplied with, and stipulating the length of time within which the violation or noncompliance must cease. If at the expiration of the stipulated length of time the violation or noncompliance shall still continue, the board of health shall at once report the violation and noncompliance to the State commissioner of health, who shall at once give a hearing to and take the proof of the persons charged with such violation or noncompliance and investigate the matter, and if he finds a violation or noncompliance to exist he shall at once certify the fact to the board of health of the municipality, which shall immediately bring an action in a court of record, which action shall be tried in the county wherein the cause of action arose against the person or corporation responsible for the violation or the noncompliance for the recovery of the penalties incurred and for an injunction against the continuation of the violation or the noncompliance.

SEC. 79d. *Penalties.*—The penalty for the discharge of sewage from any public sewer system into any of the waters of the State

without a duly issued permit for which a permit is required by this act shall be five hundred dollars, and a further penalty of fifty dollars per day for each day the offence is maintained. The penalty for the discharge of sewage from any public sewer system into any of the waters of the State without filing a report for which a report is required to be filed with the board of health of the municipality shall be fifty dollars. The penalty for the discharge of refuse or waste matter from any shop, factory, mill, or industrial establishment for which a permit is required by this act without such permit shall be one hundred dollars and ten dollars a day for each day the offence is maintained. The penalty for the discharge of refuse or waste matter from any shop, mill, factory, or industrial establishment without filing a report where a report is required by this act to be filed shall be twenty-five dollars and five dollars per day for each day the offence is maintained. The penalty for discharging into any of the waters of the State any other matter prohibited by this act besides that specified above shall be twenty-five dollars and five dollars per day for each day the offence is maintained.

SEC. 2. *Common-law rights not affected.*—Nothing in this act shall be construed to diminish or otherwise to modify the common-law rights of riparian owners in the quality of waters of streams covered by such rights, nor in the case of actions brought against the pollution of waters to limit their remedy to indemnities.

SEC. 3. This act shall take effect immediately.

[Laws of 1905, chap. 454.]

AN ACT regulating the sanitary condition of bathing establishments, and amending section two hundred and twelve of chapter twenty-five of the general public health laws, as amended by the laws of eighteen hundred and ninety-three; being renumbered by the laws of nineteen hundred, chapter six hundred and sixty-seven; number of section being originally two hundred and two.

SECTION 1. Section two hundred and twelve of chapter twenty-five of the general public health laws, as amended by the laws of eighteen hundred and ninety-three, is hereby amended so as to read as follows:

§ 212. *Regulating the sanitary condition of bathing establishments and the preservation of life at bathing places.*—It shall be unlawful for any person to maintain, either as owner or lessee, any bathing establishment of any kind, in this state, for the accommodation of persons, for pay, or any consideration, at a point less than five hundred feet from any sewer connection emptying therein, or thereat, so as to pollute in any way, the waters used by those using or hiring bathing houses at such bathing establishments; it shall be the duty of such owner or lessee to provide separate toilet rooms, with water-closets properly provided with sanitary plumbing, constructed in a manner approved by the local board of health and in such a way as not to contaminate the waters used by the bathers; it shall also be

out a similar permit from the commissioner of health. When application shall be made for a permit under either of the above provisions of this section, it shall be the duty of the commissioner to proceed to examine the application without delay, and, as soon as possible, he shall make a decision, in writing; and, within thirty days after such decision, the corporation, company, or individual making such application may appeal to any court of common pleas of the county, and said court shall, without delay, hear the appeal, and shall make an order approving, setting aside, or modifying such decision, or fixing the terms upon which said permit shall be granted. The penalty for failure to file copies of plans, surveys, and descriptions of existing waterworks within the time hereinbefore fixed, and for the construction or extension of waterworks, or the use of an additional source of supply without a permit from the commissioner of health, shall be five hundred dollars, and further penalty of fifty dollars per day for each day that the works are in operation contrary to the provisions of this act, recoverable by the Commonwealth, at the suit of the commissioner of health, as debts of like amount are recoverable by law.

SEC. 4. No person, corporation, or municipality shall place, or permit to be placed, or discharge, or permit to flow into any of the waters of the State, any sewage, except as hereinafter provided. But this act shall not apply to waters pumped or flowing from coal mines or tanneries, nor prevent the discharge of sewage from any public sewer system, owned and maintained by a municipality, provided such sewer system was in operation and was discharging sewage into any waters of the State at the time of the passage of this act. But this exception shall not permit the discharge of sewage from the sewer system which shall be extended subsequent to the passage of this act.

For the purpose of this act, sewage shall be defined as any substance that contains any of the waste products, or excrementitious or other discharges from the bodies of human beings or animals.

SEC. 5. Upon application duly made to the commissioner of health, by the public authorities having by law the charge of the sewer system of any municipality, the governor of the State, the attorney-general, and the commissioner of health shall consider the case of such a sewer system, otherwise prohibited by this act from discharging sewage into any of the waters of the State, and, whenever it is their unanimous opinion that the general interests of the public health would be subserved thereby, the commissioner of health may issue a permit for the discharge of sewage from any such sewer system into any of the waters of the State, and may stipulate in the permit the conditions on which such discharge may be permitted. Such per-

mit, before being operative, shall be recorded in the office of the recorder of deeds for the county wherein the outlet of the said sewer system is located. Every such permit for the discharge of sewage from a sewer system shall be revokable, or subject to modification and change, by the commissioner of health, on due notice, after an investigation and hearing, and an opportunity for all interested therein to be heard thereon being served on the public authorities of the municipality owning, maintaining, or using the sewage system. The length of time after receipt of the notice within which the discharge of sewage shall be discontinued may be stated in the permit, but in no case shall it be less than one year or exceed two years, and if the length of time is not specified in the permit it shall be one year. On the expiration of the period of time prescribed, after the service of a notice of revocation, modification, or change, from the commissioner of health, the right to discharge sewage into any of the waters of the State shall cease and terminate; and the prohibition of this act against such discharge shall be in full force, as though no permit had been granted, but a new permit may thereafter again be granted, as hereinbefore provided.

SEC. 6. It shall be the duty of the public authorities having by law charge of the sewer system of every municipality in the State from which sewage was being discharged into any of the waters of the State at the time of the passage of this act, to file with the commissioner of health, within four months after the passage of this act, a report of such sewer system, which shall comprise such facts and information as the commissioner of health may require. No sewer system shall be exempt from the provisions of this act against the discharge of sewage into the waters of the State for which a satisfactory report shall not be filed with the commissioner of health in accordance with this section.

SEC. 7. The penalty for the discharge of sewage from any public sewer system into any of the waters of the State without a duly issued permit in any case in which a permit is required by this act shall be five hundred dollars, and a further penalty of fifty dollars per day for each day the offense is maintained, recoverable by the Commonwealth at the suit of the commissioner of health as debts of like amount are recoverable by law. The penalty for the discharge of sewage from any public sewer system into any of the waters of the State without filing a report, in any case in which a report is required to be filed, shall be fifty dollars, recoverable by a like suit.

SEC. 8. All individuals, private corporations, and companies that, at the time of the passage of this act, are discharging sewage into any of the waters of the State may continue to discharge such sewage unless, in the opinion of the commissioner of health, the discharge

of such sewage may become injurious to the public health. If at any time the commissioner of health considers that the discharge of such sewage into any of the waters of the State may become injurious to the public health he may order the discharge of such sewage discontinued.

SEC. 9. Every individual, private corporation, or company shall discontinue the discharge of sewage into any of the waters of the State within ten days after having been so ordered by the commissioner of health.

SEC. 10. Any individual, private corporation, or company that shall discharge sewage, or permit the same to flow, into the waters of the State contrary to the provisions of this act shall be deemed guilty of a misdemeanor, and shall upon conviction be punished by a fine of twenty-five dollars for each offense and a further fine of five dollars per day for each day the offense is maintained, or by imprisonment not exceeding one month, or both, at the discretion of the court.

SEC. 11. Any order or decision, under this act, of the commissioner of health, or that of the governor, attorney-general, and commissioner of health, shall be subject to an appeal to any court of common pleas of the county wherein the outlet of such sewer or sewer system, otherwise prohibited by this act, is situated; and said court shall have power to hear said appeal, and may affirm or set aside said order or decision, or modify the same, or otherwise fix the terms upon which permission shall be granted. But the order or decision appealed from shall not be superseded by the appeal, but shall stand until the order of the court, as above.

Approved the 22d day of April, A. D. 1905.

[Laws of 1905, No. 223.]

AN ACT authorizing and empowering cities, owning and operating waterworks systems, to enter, by any of its employes, upon private lands through which may pass any stream or streams of water supplying such cities, for the purpose of patrolling the drainage area, and making investigations or inquiries pertaining to the condition of the stream or streams, sanitary or otherwise.

SEC. 1. *Be it enacted, &c.*, That any city owning and operating a waterworks system is hereby authorized and empowered to enter, by any of its employes, upon private lands through which may pass any stream or streams of water supplying such city, for the purpose of patrolling the drainage area of such stream or streams, and making investigations or inquiries pertaining to the condition of the stream or streams, sanitary or otherwise; Provided, however, That any injury or damage done to the property so entered upon shall be paid by such city.

Approved the 2d day of May, A. D. 1905.

VERMONT.

[Statutes, 1894, p. 842, Preservation of public health.]

SEC. 4695. If any person puts or causes to be put a dead animal or animal substance into or upon the bank of a lake, pond, running stream, or spring of water so that it is drawn or washed into the same, and suffers it to remain therein, he shall be fined not more than twenty dollars and not less than five dollars.

[Laws of 1898, No. 150, p. 115.]

AN ACT in amendment of act No. 137 of the acts of 1894, relating to pollution of the waters of Missisquoi River.

It is hereby enacted by the general assembly of the State of Vermont:

SECTION 1, number 137, of the public acts of 1894, is hereby amended so as to read as follows: "A person owning or operating a mill who shall by himself or his agent deposit or suffer to be deposited any sawdust, shavings, or any mill refuse in the waters of the Missisquoi River above Enosburgh Falls, or in any of the tributaries of said Missisquoi River above Enosburgh Falls, shall be fined not less than twenty dollars nor more than one hundred dollars, in the discretion of the court, for each offence."

SEC. 2. This act shall take effect from March 1st, 1899. Approved November 16th, 1898.

[Laws of 1902, No. 115, p. 144.]

AN ACT to prevent the pollution of the sources of water supply, as amended by No. 141, Laws of 1904.

It is hereby enacted by the general assembly of the State of Vermont:

SECTION 1. The State board of health shall have the general oversight and care of all waters, streams, and ponds used by any cities, towns, villages, or public institutions, or by any water or ice companies in this State as sources of water supply, and of all springs, streams, and water courses tributary thereto. It shall have power to call for, and when it calls for it shall be provided with maps, plans, and documents suitable for such purposes, at the expense of such city, town, village, public institution, water or ice company, and shall keep records of all its transactions relative thereto.

Said board shall have authority to prohibit any town, city, village, public institution, individual or water or ice company from using water or ice from any given source whenever in its opinion the same is so contaminated, unwholesome and impure that the use thereof endangers the public health. And the court of chancery shall have

jurisdiction and power, upon application therefor by the State board of health, to enforce by proper order and decree any order, rule or regulation which said board may make under and by virtue of this section.

SEC. 2. Said board may cause examinations of such waters to be made to ascertain the purity and fitness for domestic use, or their liability to impair the interests of the public or of persons lawfully using them or to imperil the public health. It may make rules and regulations to prevent the pollution and to secure the sanitary protection of all such waters as are used as sources of water supply.

SEC. 3. The publication of an order, rule, or regulation made by the board under the provisions of sec. 2 or sec. 6 hereof, in the newspaper of any town or village in which such order, rule, or regulation is to take effect, or if no newspaper is published in such city, town, or village, the posting of a copy of such order, rule, or regulation in three public places in such city, town, or village, shall be legal notice to all persons, and an affidavit of such publication or posting by the persons causing such to be published or posted, filed, and recorded with a copy of the notice in the office of the clerk of such city, town, or village shall be admitted as evidence of the time at which and the place and manner in which the notice was given.

SEC. 4. Said board shall include in its biennial report to the general assembly its doings for the preceding biennial term, and shall recommend measures for the prevention of the pollution of such waters and for the removal of polluting substances in order to protect and develop the rights and property of the State therein, and to protect the public health, and shall recommend any legislation or plans for systems of main sewers necessary for the preservation of the public health and for the purification and prevention of pollution of the ponds, streams, and waters of the State. It shall also give notice to the State's attorney for the county wherein any violation of the law relative to the pollution of the water supplies occurs. It shall have the power to employ such expert assistants as it considers necessary.

SEC. 5. Cities, towns, villages, and persons shall submit to said board for its advice their proposed systems of public water supply or for the disposal of drainage or sewage. Said board shall consult with and advise the authorities of the cities, towns, villages, and persons having or about to have systems of public water supply, drainage, or sewage, as to the most appropriate sources of water supply, and the best methods of assuring its purity or as to the best methods of disposing of their drainage or sewage, with reference to the existing and future needs of other cities, towns, villages, or persons which may be affected thereby. It shall also consult with and advise persons engaged or intending to engage in any manu-

facturing or other business whose drainage or sewage may tend to pollute any water or source of water supply as to the best method of preventing such pollution, and it may conduct experiments to determine the best methods of purification or disposal of drainage or sewage. No person shall be required to bear the expense of such consultation, advice, or experiments. In this section the term "drainage" means the rainfall, surface, and subsoil water only, and "sewage" means domestic and manufacturing filth and refuse.

SEC. 6. Upon petition to said board by the mayor of a city, the selectmen of a town, the trustee or bailiff of a village, the managing board or officer of any public institution, or by a board of water commissioners, or the president of a water or ice company, stating that manure, excrement, garbage, or any other matter is polluting or tending to pollute the water of any stream, pond, spring, or water course used by such city, town, village, institution, or company as a source of water supply, the board shall appoint a time and place within the county where the nuisance or pollution is alleged to exist, for hearing, and after notice thereof to parties interested and a hearing, if in its judgment the public health so requires, shall, by an order served upon the party, company, or premises so polluted, prohibit the deposit, keeping, or discharge of any such cause of pollution, and shall order him to desist therefrom and to remove any such cause of pollution; but the board shall not prohibit the cultivation or use of soil in the ordinary methods of agriculture if no human excrement is used therefor.

Said board shall not prohibit the use of any structure which was in existence at the time of the passage of this act upon a complaint made by the board of water commissioners of any city, town, or village, or by any water or ice company, unless such board of water commissioners or company files with the State board a vote of its city council, selectmen, trustees, or bailiffs, or company, respectively, that such city, town, village, or company will, at its own expense, make such change in said structure or its location as said board shall deem expedient. Such vote shall be binding on such city, town, village, or company. All damages caused by such change shall be paid by such city, town, village, or company, and if the parties can not agree thereon such city, town, village, or company shall tender to the parties sustaining damages such a sum of money as in their judgment is a reasonable compensation for the damages sustained. Whoever is aggrieved by an order under the provisions of the preceding section, or with the sum so tendered as damages, may appeal therefrom in the manner provided in Vermont statutes, sec. 3314 to 3317, inclusive, relating to highways. But the notice therein provided for shall be served on the party or parties who are petitioners in fact under section 6 of this act, and also upon the State board of

health. If the appeal be only from the compensation for damages, the order of the board shall be complied with during the pendency of such appeal unless otherwise authorized by said board.

SEC. 7. The court of chancery shall have jurisdiction and power, upon application thereto by the State board of health or any party interested, to enforce its orders, or the orders, rules, and regulations of said board of health, and to restrain the use or occupation of the premises or such portion thereof as said board may specify, on which said material is deposited or kept or such other cause of pollution exists, until the orders, rules, and regulations of said board have been complied with.

SEC. 8. Said board of health may by itself, its servants and agents, enter any building, structure, or premises for the purpose of ascertaining whether sources of pollution or danger to the water supply there exist and whether the rules, regulations, and orders aforesaid are obeyed.

SEC. 9. Whoever violates any rule, regulation, or order made under the provisions of section 2 or section 6 of this act shall be punished for each offense by a fine of not more than five hundred dollars to the use of the State, or by imprisonment for not more than one year, or by both such fine and imprisonment.

SEC. 10. No sewage, drainage, refuse, or polluting matter of such kind and amount as either by itself or in connection with other matter will corrupt or impair the quality of the water of any pond or stream used as a source of ice or water supply by a city, town, village, public institution, or water company for domestic use, or render it injurious to health, shall be discharged into any such streams, ponds, or upon their banks.

SEC. 12.[a] The court of chancery, upon the application of a mayor of a city, the selectmen of a town, the trustees or bailiffs of an incorporated village, the managing board or officer of a public institution, or a water or ice company interested, shall have jurisdiction in equity to enjoin the violation of the provisions of section 10.

SEC. 13. Whoever wilfully deposits excrement or foul or decaying matter in water which is used for the purpose of domestic water supply or on the shore thereof within five rods of the water shall be punished by a fine of not more than fifty dollars or by imprisonment for not more than thirty days; and a constable of a town or police officer of a city or village in which such water is wholly or partially situated may act within the limits of his city or town, and any executive officer or agent of a water board, board of water commissioners, public institution, or water company furnishing water or ice for domestic purposes, acting upon the premises of such board, institution, or company,

[a] Section 11 repealed.

and not more than five rods from the water, may without a warrant arrest any person found in the act of violating the provisions of this section and detain him until complaint may be made against him therefor. But the provisions of this section shall not interfere with the sewerage of a city, town, village, or public institution, or prevent the enriching of land for agriculture by the owner or occupant thereof.

SEC. 14. Each member of the State board of health shall receive four dollars per day and actual expenses while in the discharge of the duties imposed by this act. The State auditor is directed to draw his order on the State treasurer every six months for such sums as are necessary to meet the expenses of said board under the provisions of this act.

Approved December 12, 1902.

GENERAL RULES.

The foregoing compendium of common and statute law may be summarized and stated in a few general rules, which will perhaps be useful to property owners and also to officers charged with the duty of protecting health and property rights in waters.

In the nature of the case these rules can be only general, and many exigencies will appear in which more particular instructions must be obtained from the consultation of text-books and decisions or from the advice of counsel.

I. RIGHTS AND DUTIES OF RIPARIAN OWNERS.

Every riparian owner has the right—

1. To use the waters of streams, navigable or otherwise, which flow across or along his property for the ordinary purposes incidental to domestic life and agriculture, including grazing.

2. To use such waters for water power and for all kinds of manufacturing purposes which do not sensibly diminish the quantity which flows on for the use of lower proprietors nor change the quality of the waters to any appreciable extent, nor interfere with the use of the stream, if navigable by the public.

3. To have such waters flow to him from the premises of higher proprietors not unreasonably diminished nor diverted nor rendered impure by the farming or domestic uses to which the waters are subjected by higher proprietors.

4. To have such waters flow to him not sensibly changed in quality by any manufacturing or other uses to which they may have been put by higher proprietors.

5. To have such waters flow to him in their natural bed, unpolluted by any deposits of filth or any other substance in the bed or channel

previously traversed by them. But 3, 4, and 5 do not apply to riparian owners in those States in which the doctrine of prior appropriation is the law. (See pp. 21-23.)

Conversely, it is the duty of every riparian owner—

1. To so guard his use of the waters of streams which flow across or along his property for domestic and agricultural purposes as not unreasonably to divert nor diminish nor render impure such waters.

2. To refrain from every use in manufacturing which will divert or sensibly diminish the quantity of the waters which flow onward to the lower proprietors or render them appreciably different in quality.

3. To refrain from depositing any filth or other substance in the bed of such streams in such a manner or to such an extent as will cause the waters to flow to the lower proprietors out of their natural bed or will in anywise pollute them or render them impure.

Where the doctrine of prior appropriation is in force the appropriator must confine his use of the appropriated water to the use for which he has appropriated it and take only so much as is reasonably necessary to accomplish that purpose. He may not pollute the stream wantonly, nor by using it for purposes not included in his appropriation. Subject to these restrictions, the prior appropriator has the right to divert from the stream and use as much of the water as is necessary to accomplish the purpose for which it was appropriated.

II. RIGHTS AND DUTIES OF MUNICIPAL CORPORATIONS.

Considered as corporate entities, municipal corporations have such rights and powers only as are conferred upon them by statute, either expressly or by necessary implication.

When, under due authority, they become the owners of lakes, reservoirs, and natural streams, they have the same rights to pure water, and are charged with the same duties as are other riparian proprietors.

If authorized to construct a system of sewers draining into a stream, such authority does not exempt them (except in the State of Indiana) from the duty not to pollute the stream to the damage of lower proprietors.

The rights of property owners, specified in 3, 4, and 5 above are property rights and can not be taken away from owners for public use except upon payment therefor of an amount determined by constitutional condemnation proceedings authorized by statute.

Therefore, until municipal corporations have, by such proceedings, acquired the rights of all lower proprietors and paid for them, they are required in all cases to refrain from the pollution of streams to the same extent as private owners.

III. RIGHTS AND DUTIES OF THE PUBLIC.

By "the public" is meant that indefinite number of individuals, whether larger or smaller, who occupy as a common habitation a neighborhood, village, town, State, or country. Rights and duties which affect inhabitants of the neighborhood, village, town, State, or country as a whole, or a considerable but indefinite number of them, are called "public" rights and duties.

The public, in this sense, aside from the right to use navigable waters for commerce, has the right to enjoy the natural waters and the air which passes over them, so far as life and health are affected by these elements, in a condition so near that in which nature left them that their use will not destroy nor threaten life nor injure health.

And, reciprocally, the public, and each member of it, is charged with the duty not to pollute the natural waters upon which the community depends for life and health in any manner that will render the continued use of the waters, or of the air which passes over them, destructive of or injurious to the life or health of the community.

PUBLIC RIGHTS AND DUTIES ENFORCED BY STATUTE.

The rights and duties attempted to be expressed under III have received some recognition by the courts apart from statutory enactments. They have been enforced chiefly, however, through legislation. These rights and duties have received full recognition, and an active effort has been made to provide an efficient sanction for their enforcement by the legislatures of all the States included in Class II and Class III, as hereinbefore stated. These classes include thirty-eight of the States and Territories.

These statutes, not being in derogation of common-law rights, have been construed as remedial statutes and not unconstitutional, although in some cases they may seem to interfere with prescriptive rights. No one can acquire by prescription a right to do an act which menaces public health or destroys public comfort.

PROGRESS OF LEGISLATION.

It will have been noticed that public opinion, as expressed in public laws, is steadily progressing in the direction of a full, complete, and comprehensive enforcement of all the rights and duties of riparian owners, of municipal corporations, and of the public, as summarized above. Each advance in statutory regulation is an advance in that direction, and more especially in the direction of regulating and enforcing public rights and municipal rights and duties.

Private owners, from time immemorial, have been active in protecting their riparian rights as against other private owners. But the effect of pollution upon public health has not, until a comparatively recent period, been brought prominently into notice. The pollution of streams by cities and private persons has, accordingly, not received the attention which it deserved. This state of affairs is now rapidly passing away. Courts have shown themselves fully alive to the existence and validity of public rights in that respect, and the legislatures in Class III, comprising the States of Connecticut, Massachusetts, New Hampshire, New York, New Jersey, Minnesota, Vermont, and Pennsylvania, which has come into this class by legislation enacted in 1905, have made enactments calculated so to control such pollution as eventually to prevent all danger to public health.

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[Water-Supply Paper No. 152.]

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